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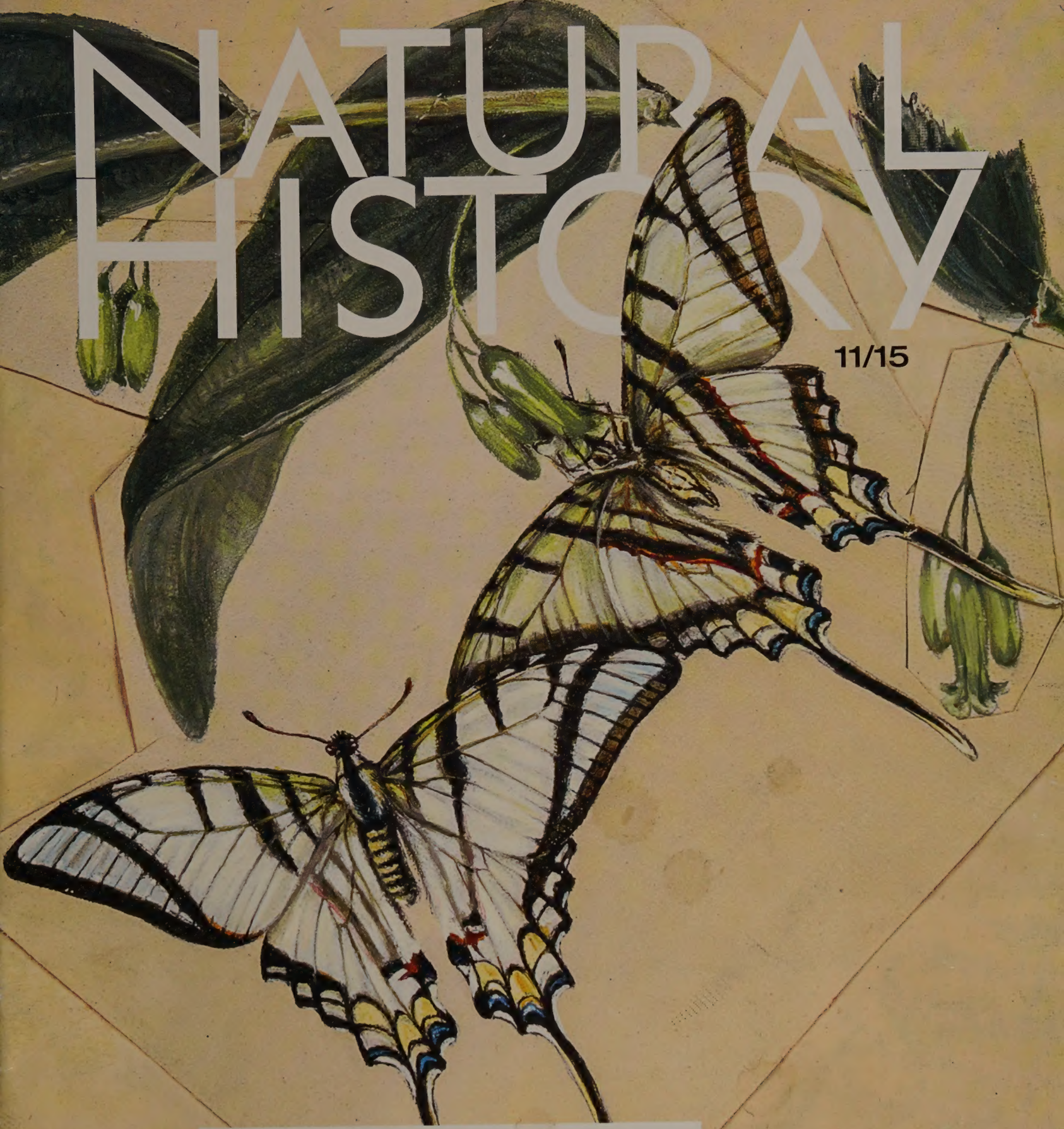

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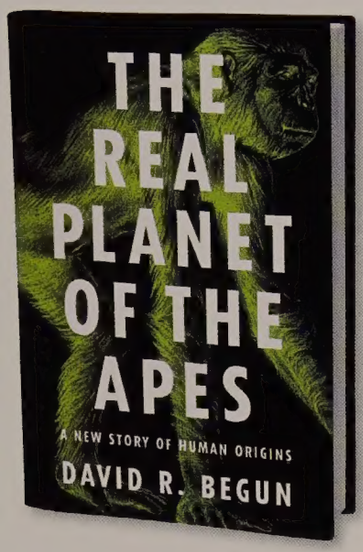

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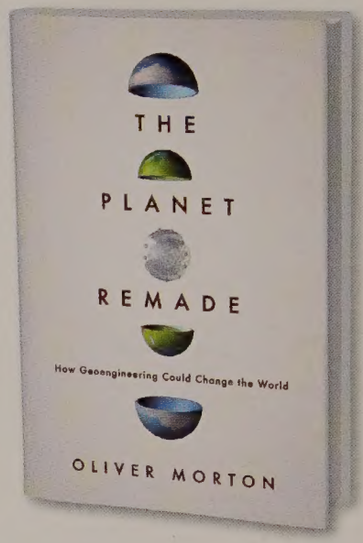

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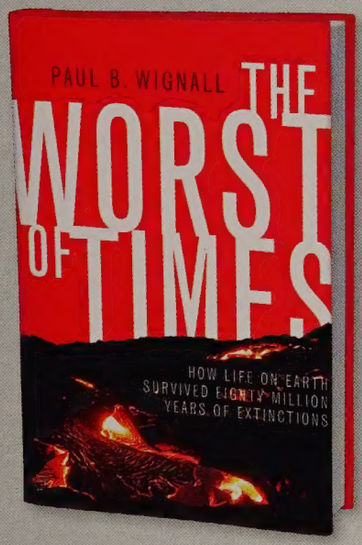

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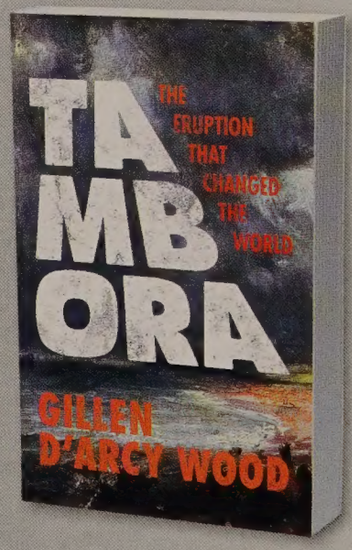

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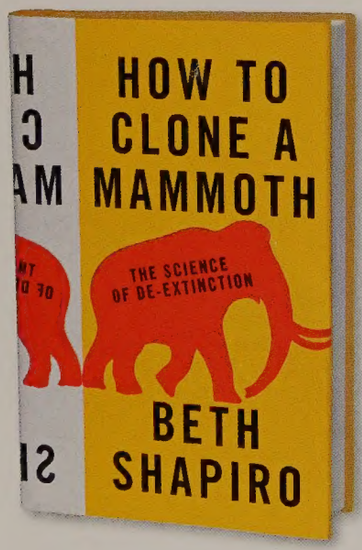

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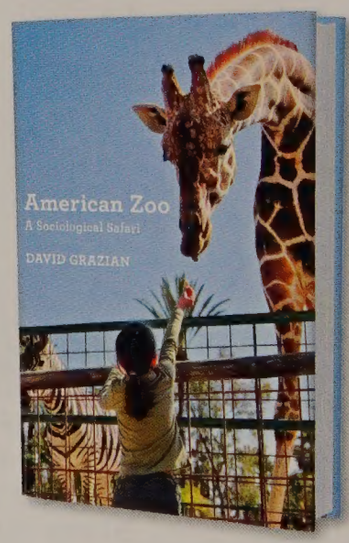

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—Shamus Khan, author of *Privilege*

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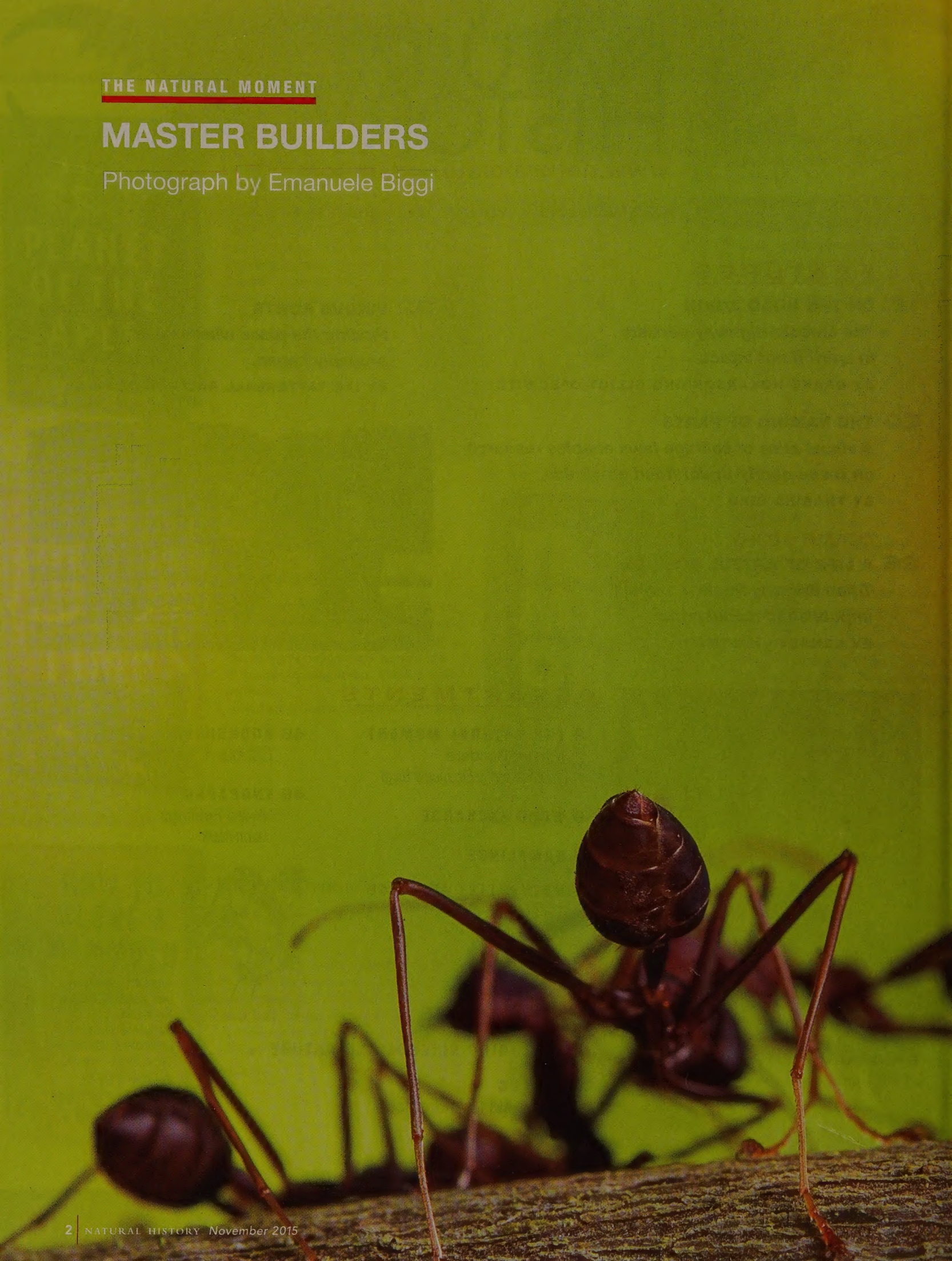
Illustration by Titian Ramsay Peale II

THE NATURAL MOMENT

MASTER BUILDERS

Photograph by Emanuele Biggi



THE NATURAL EXPLANATION BY KATI MOORE

◄ *See preceding two pages*

Weaver ants (*Oecophylla smaragdina*) are named for their unique method of nest construction in tree canopies, folding and connecting leaves to one another. When two leaves are too far apart for a sole ant to reach, other ants join the first, climbing on its back to create a chain. Once the ant ladder reaches the leaf, the ants crawl backward over each other, drawing the leaves together.

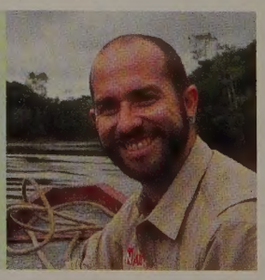
Some of the ants then hold the leaves together with their jaws while others use silk from the colony's larvae to create a tight seam between the leaf edges. The ants hold the larvae in their jaws and tap them with their antennae, releasing the silk in strings.

Photographer Emanuele Biggi first encountered weaver ants in Burkina Faso. His companion dared him to eat one (both the ants and their larvae are edible), and he did—the ants have a slightly sour taste, he said. A few years later, Biggi traveled to the state of Sabah, Malaysia on the island of Borneo specifically to see these tiny creatures, which are also found in India and Australia. He took the photos shown here in the mangrove forests near Sabah's Kota Kinabalu Wetlands.

Though weaver ants lack a stinger, their bite is accompanied by a spray of formic acid, which helps to subdue prey, though the ants' great numbers are their most effective offensive and defensive weapon. Their aggressive behavior has made weaver ants useful to citrus farmers for thousands of years as a form of biocontrol. Farmers tie strings between nests and fruit trees to facilitate colonization, and the ants keep away pests that carry diseases harmful to fruit trees.

The ants are also farmers themselves. They harvest honeydew from scale insects, which they protect from predators. While such mutualism has been observed in other ant species, weaver ants are the only ones known to protect their livestock by building leaf fortresses around them.

Biologist **Emanuele Biggi,** Ph.D., is an award-winning photographer focusing on "microcosm" animals, conservation of nature, and science-at-work photography. He describes himself as "a person that doesn't fear to be low on the ground or close to a bark to witness the marvel of this beautiful blue planet, be it a lion or a dung beetle." He is a scientific advisor to Italian parks and nature reserves, a TV presenter, and a curator of scientific expositions. View more of his work at www.anura.it.



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Collectables

Of the 728 butterflies collected by Gary Ross ["My Wallace Moment," 9/15] where were they headed? Are they destined for a scientific institution or someone's private collection? This episode seems to me a little like trophy hunting, especially if these species are covered by CITES.

Janeann P. Erickson
Petaluma, CA

GARY ROSS REPLIES:

The collection of specimens (particularly those of insects) is still regarded as a legitimate scholarly and scientific enterprise. This is particularly true when it comes to regions of the world—such as New Guinea—that are off the beaten path and rarely visited by outsiders.

In late 2006, I donated my entire lifelong collection of insect specimens (and their cases) to the McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, University of Florida, Gainesville—a research-teaching facility that is noted as one of the leading repositories of lepidopterans in the world. There they are accessible to research scientists and students from around the world. In addition, many of these institutions mount periodic exhibits based on their collections. These displays are crucial for inspiring the public to safeguard our dwindling biological diversity.

Whereas I cannot vouch for other members of the 1990 expedition, I am certain that the vast majority of private butterfly/moth collectors eventually bequeath their personal collections to academic institutions. As such, most collections eventually become an invaluable part of a permanent and protected inventory of the world's diminishing fauna. Not to be overlooked is the fact that recreational entomologists—unlike non-professionals in other branches of the natural sciences—traditionally contribute their observations and data to formal publications and discussions. As such, the collecting of insect specimens by both professionals and non-professionals is, for the most part, still encouraged and productive.

Path of Good Intentions

Druin Burch in his article "Mounting Evidence" [6/15] takes the position that statin drugs are prescribed to lower serum cholesterol values and thus reduce the risk of cardiovascular disease. This position is also taken by many physicians and by the suppliers of statin drugs. There are, however, numerous reports in the medical and scientific literature showing that data from numerous clinical studies contradict these claims. After twenty-five years as a thoracic surgeon, Dwight C. Lundell, MD [author of *The Great Cholesterol Lie*] has focused attention on this issue and feels that the use of statins to prevent heart disease is dangerous due to serious, disabling side effects. Further, they have not been shown effective in women of any age nor in anyone over the age of 65. Middle-aged men, who have had a previous heart attack, "may" benefit.

Richard F. Wallin
Bonita Springs, FL

DRUIN BURCH REPLIES:

Medicine has moved on somewhat from a discipline in which opinions (and the eminence of those who hold them) are seen as gold standards when it comes to identifying truth. Those who have reached opinions about the natural history of human pathophysiology and therapeutics have occasionally been right, far more often wrong, but they have almost always been well intentioned, thoughtful, intelligent, and highly educated. What they lacked was method. Statins have not been assessed on the basis of opinion, nor on case reports and poor quality studies, which amount to cherry-picked anecdotes, but instead on the basis of reliable experiments. As so often in medicine, in order to be reliable these have been large-scale, long-term, randomized, double-blind, controlled trials. The conclusions of these trials are at odds with the views put forward by Richard Wallin. Those who wish to read more about what makes a fair and reliable test in medicine might enjoy the book *Testing Treatments*, which is freely available on a website of that name, or my own history of clinical trials' stuttering development, *Taking the Medicine*.

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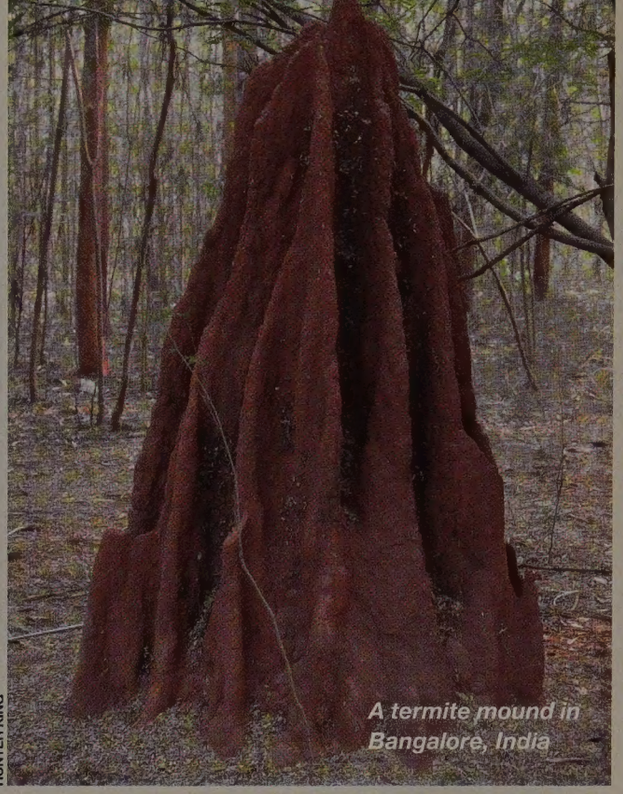


HUNTER KING

A termite mound in Bangalore, India

Fungus-harvesting termites *Odontotermies obesus* build one– to two-meter-high fluted mounds above their subterranean nests. As the termites construct these cathedral-like, porous clay structures, they build passages within that are subsequently traveled for further construction and repair. These conduits are also thought to regulate microclimate in the nest below—but until recently, how they control temperature, moisture, and respiratory-gas exchange remained unknown.

To investigate this phenomenon, Hunter King, Samuel Ocko, and Lakshminarayanan Mahadevan at Harvard University first built a highly sensitive probe to measure carbon dioxide, humidity, and temperature inside the mound—and to gather the data quickly. Termites are known to attack foreign objects often within moments. "They'll gunk the probe up with mud, saliva, and sometimes they'll fry themselves trying," said Mahadevan. Probes were inserted at various locations (base, top, middle, inside) of inhabited mounds, and at different times during the day and night. The same measurements were also taken from an abandoned mound.

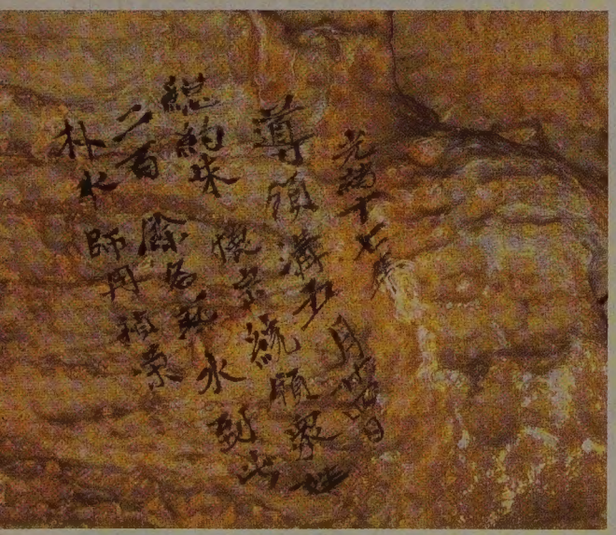
The researchers found that the architecture of the mound enables the structure to function like a giant lung, inhaling and exhaling once every 24-hour period. During the day, warm air travels through conduits up the sides of the mound, pushing cooler air down through more central chimneys. At night, this convection cell reverses course to keep the nest warm. The porosity of the mound allows for carbon dioxide exchange with the environment as the air moves past the exterior walls.

An understanding of termite mound ventilation could lead to more efficient management of human buildings. Mahadevan says the mound works like an engine, using temperature oscillations to do the work of moving air. "It is possible, at a reasonable scale, to use environmental fluctuations to get work out of [a structure]." He hopes engineers might be able to learn some lessons from his team's study of mound ventilation for efficient building design, and in the meantime take advantage of the thermal gradients in existing buildings to power ventilation. He wonders, "Could it be as easy as the coordinated opening and closing of windows and doors throughout the day?" (*PNAS*)

—Niki Wilson

Drought Seeds Unrest

The Dayu Cave, on the southern slope of the Qinling Mountains in central China, is an aquifer, a natural rainwater stockpile where permeable rock conserves water when the surface is parched. Inscribed on this cave's walls are dated accounts of at least seventy visits by local people over the past 500 years, to search for water and pray for rain. Among them are references to seven major droughts. Chinese historical records suggest that periods of social upheaval and drought tend to coincide, but this relationship has been disputed.



LIANGCHENG TAN

An inscription from the Dayu Cave which states: "On May 24th, 17th year of the Emperor Guangxu period, Qing Dynasty (June 30, 1891 CE), the local mayor, Huaizong Zhu, led more than 200 people into the cave to get water. A fortuneteller named Zhenrong Ran prayed for rain during a ceremony."

The Dayu Cave offers a unique opportunity to scientifically test whether climate variation and societal unrest are linked. In addition to the dates and notes etched into the wall, the cave contains stalagmites, cave-floor growths of mineral deposits that slowly accumulate as water and rock react. The mineral deposits act like tree rings, making stalagmites reliable indicators of both age and climate change.

Liangcheng Tan, a climatologist at the Chinese Academy of Sciences in Xi'an, worked with a multinational group of ten other scientists to analyze the contents of a stalagmite from Dayu Cave. The geological team measured thorium and uranium to calculate the age of the stalagmite, which began to grow in 1265. They then analyzed amounts of a specific form of oxygen and a specific form of carbon, and found that high oxygen and carbon levels during the stalagmite's formation correlated with sparser precipitation. These periods matched up perfectly with historical records of major social problems, including "starvation and cannibalism" and "fierce conflict between government and civilians," and also with the inscriptions telling of drought. For example, the highest oxygen level occurred in the year 1590. The inscriptions for this time say the "mountains are crying due to drought" and that local people "came to the cave to get water," even in the monsoon season, when the rains should have been strongest.

The findings confirm the link between drought events and societal turmoil in the past. Alarmingly, this study also predicts dryer than average conditions for the Qinling Mountains in the near future. Two water transfer projects in central China depend on rain from the southern mountains, and the region provides a habitat for endangered species including the golden monkey and giant panda. Clearly, taking adaptive measures—such as protecting ground water—to prepare for possible drought is of vital importance today. (*Scientific Reports*)

—Judy Rice

Bait and Switch

Mate choice—a crucial decision that directly impacts an individual's evolutionary fitness—has long been assumed to be rational. And rational decisions obey certain mathematical rules. Regularity is one of them: if choice A is preferable to B in the absence of C, then A is also better than B in the presence of C.

Human behavior does not always follow the rules of rationality. One common violation of regularity is the "decoy effect." For example, when considering which car to buy, someone might care more strongly about cost and slightly less about fuel efficiency. Given the choice between car A, with a lower price and moderate fuel efficiency, and car B, with a higher price and better fuel efficiency, the person will choose car A. But in the presence of a third, even higher-priced, more fuel-efficient car C—the "decoy"—the buyer will change and select car B.

To unravel whether other animals are also fooled by the decoy effect, Amanda M. Lea and Michael J. Ryan, of the University of Texas at Austin and the Smithsonian Tropical Research Institute, Panama, designed a study of mate choice strategy in túngara frogs (*Physalaemus pustulosus*). In the wild, female túngara frogs visit breeding sites, listen to males, then select and approach mates based on their calls. So, Lea set up speakers in a dark, soundproof chamber, and observed with infrared cameras how females, placed in the center, responded to playbacks of three male calls that differed in rate and pitch. With only two speakers playing calls A and B, females generally approached call A. When a third speaker played call C, however, females chose call B. The frogs' preferences switched to a seemingly lower quality, "irrational" choice after a third song choice was introduced.

Do we know why the decoy effect occurs in frogs, or in humans? "No, not always," said Lea, adding, "this is a really active area of research." One possibility is that perfect rationality requires too much cognitive processing to be worthwhile. Regardless, understanding how mating decisions are made can clarify the theory of sexual selection. (*Science*)

—Lesley Evans Ogden

*Two male túngara frogs (*P. pustulosus*) compete through vocal contests for the opportunity to mate.*

AMANDA M. LEA

Veritas in Vino

For oenophiles, terroir is a profound concept bordering on the mystical. It refers to the unique essence of a wine derived from where and how the grapes were grown. Factors such as soil composition, light exposure, and viticultural practices combine to make the yields from different vineyards unique.

To grasp terroir from an empirical standpoint, a mainly Italian research team has dug deeply into the biochemical nitty-gritty of a wine grape variety called Corvina. They sampled grapes from seven vineyards across three growing regions in the province of Verona—"not only the city of Romeo and Juliet, but also an important wine district for Italy," said Flavia Guzzo, a professor of botany at the University of Verona and senior investigator of the new research. The vineyards differed in many potential components of terroir, including height above sea level, loam, sand, clay, and lime content of their soils, and soil levels of phosphorous and magnesium.

Initially, in 2013, the team focused on the transcriptome, or the expression of a grape berry's genes. Frustratingly, the vast transcriptome of 30,000 biochemicals by itself did not readily show links between a grape and its environment. In their new paper, the researchers turned their attention to the Corvina samples' metabolome, which consists of the various substances a grape produces within itself. The metabolites of interest were those made in response to the environment.

In the new study the chemical analysis of around 500 metabolites did demonstrate subtly distinct biochemistries for berries from each of the growing regions, and even individual vineyards. The results suggest the terroir concept is very real and measurable. For example, anthocyanins—the molecules behind grape skin coloration—varied from place to place, while certain varieties of resveratrol—an antioxidant sold as a human health supplement—characterized the vineyards in one particular growing region.

Teasing out these slight differences required a fresh statistical approach to perceive variations beyond the dominant influence of vintage, or the year in which the grapes were grown, with its attendant major impacts of weather patterns and water availability. Furthermore, the newly discovered metabolite variances remain somewhat abstract, as their effects on human taste are not yet clear. "We cannot say if they can be perceived, at the end, in the glass of wine," said Guzzo. It would seem more research, as well as tasting, are in order. (*BMC Plant Biology*)

—Adam Hadhazy

A gaseous disk around a star where planetisimals begin to form

NASA/JPL-CALTECH/T. PYLE (SSC)

Rock Collections

In order to form gas-giant planets such as Jupiter and Saturn, consisting primarily of hydrogen and helium, it has been widely held that first a solid core had to form—one that was roughly ten times the size of Earth, and one that would form before the solar nebula dissipated in about one to ten million years. Modelling such an event has been a challenge.

Recent models have shown how centimeter-to-meter-sized pieces of stone, or "pebbles," are first attracted to each other by aerodynamic drag, and then gravity binds them together to form "planetisimals," objects 100 to 1,000 kilometers in size. Like a rolling snowball, these planetesimals gather leftover pebbles and form cores ten times the size of Earth in only a few thousand years.

When computer simulations were run, however, these models did not reproduce the structure of the Solar System, according to Harold F. Levison of the Southwest Research Institute and NASA Solar System Exploration Research Virtual Institute in Boulder, Colorado. Rather than four large outer planets, "they made hundreds of planets the mass of Earth," he said.

Levison and colleagues have developed a tweak that solves the problem. The key to their model is timing: they allow much longer for planetisimals to interact. The largest planetisimals scatter the smaller ones out of the gaseous disk, which stifles their growth, enabling the largest ones to develop into planets. Simulations with this adjustment in place produce a model that closely resembles the Solar System with four or five large gaseous planets, roughly five to fifteen times Earth's distance from the Sun. It seems plausible from this research that huge planets can indeed form from mere pebbles. (*Nature*)

—Harvey Leifert

Less Ice, More Food

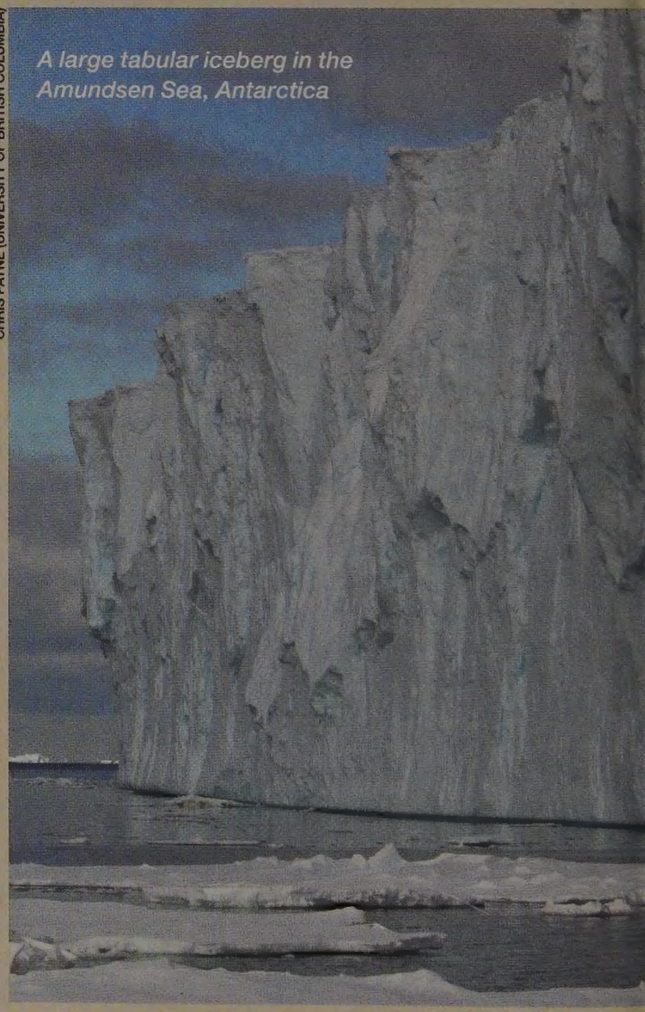
Within the icy waters surrounding Antarctica are hot spots of life where the ocean remains atypically open much of the year. Known as polynyas, these mostly ice-free coastal waters host massive phytoplankton blooms, attracting numerous marine mammals and birds and consuming huge amounts of climate-changing carbon dioxide. What drives the growth of these valuable phytoplankton blooms at the base of the marine food chain?

To answer this question, instead of enduring Antarctica's harsh and isolated conditions, Kevin R. Arrigo and two colleagues at Stanford University have relied on the increasing amount of satellite data on the region. They examined how six environmental factors—sea surface temperature, polynya size, length of time polynya waters remained mostly ice-free, width of continental shelf beneath polynyas, light availability, and the melting rate of neighboring glacial ice shelves—influenced the abundance and productivity of phytoplankton in forty-six Antarctic polynyas from 1998-2014.

Surprisingly, neither light availability nor the number of ice-free days contributed much to the magnitude of blooms. Instead, the dominant factor spurring phytoplankton productivity in polynyas was the melting rate of ice sheets. Arrigo's team knew that dissolved iron was an important nutrient limiting phytoplankton growth, but did not realize that melting glaciers could remove this limitation by releasing iron. Wider continental shelves, where iron in seabed sediments can become resuspended and available to phytoplankton, also contributed to phytoplankton abundance.

The six analyzed factors explained approximately 80 percent of the difference in phytoplankton abundance and productivity among polynyas. Yet as a warming climate speeds Antarctic glacial melting, Arrigo predicts that "the waters around Antarctica, home to so many large populations of birds, seals, and whales, are likely to become even more productive." How that change ultimately impacts the marine food web in these highly variable hot spots remains to be seen. (*Journal of Geophysical Research: Oceans*)

—Ashley Braun



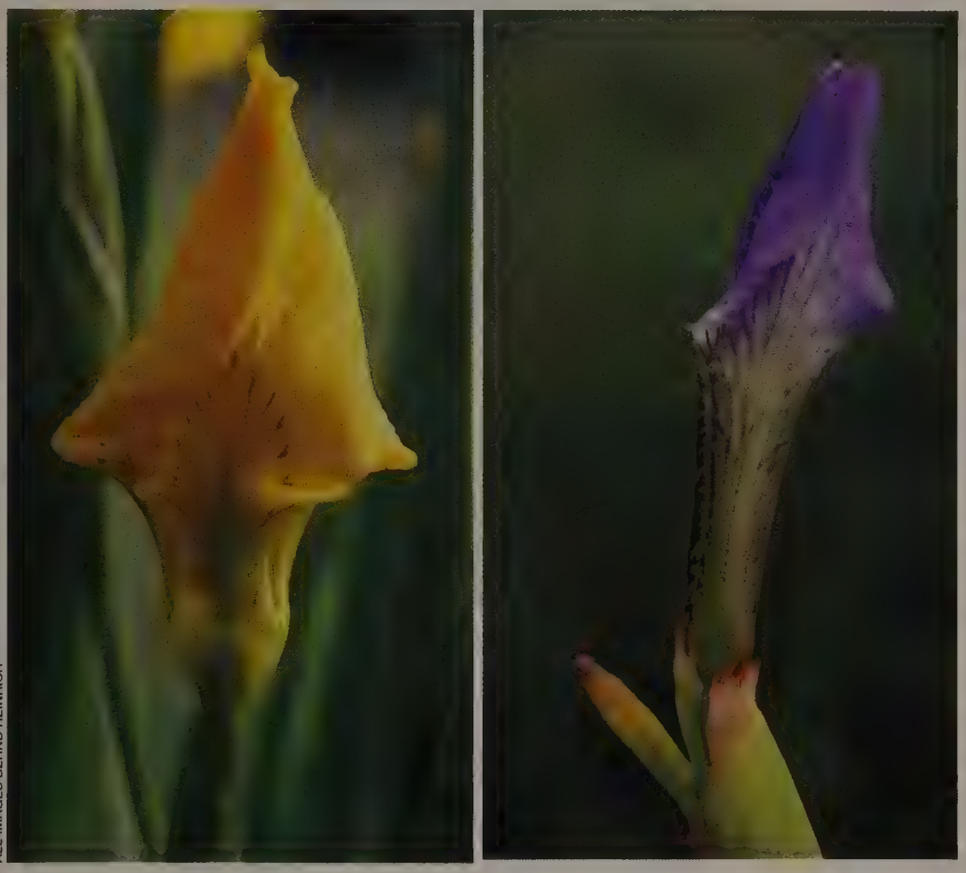
A large tabular iceberg in the Amundsen Sea, Antarctica

CHRIS PAYNE (UNIVERSITY OF BRITISH COLUMBIA)

Twists and Turns

Uneven handedness

I had been studying iris flowers ["Curious Yellow," 5/15] because I got hooked by an incidental observation: the petals of an iris flower, when they are wrapped around each other in the bud, are *upright*, but when unfurled in the flower they point *down*. The change in direction happens in a fraction of a second. The grip of the petals, which is necessary to store the energy for their eventual outward flip for the bud opening, depends on their twist around each other. I had at first taken the direction of that twist for granted, because it seemed irrelevant to the mechanism. From all the sketches that I had made, however, I noticed the petals unfurled in a counterclockwise direction. That seemed odd. Now, the direction of the twist had my attention. I made counts in the flower patch next to my cabin, expecting to see roughly equal numbers of clockwise and counterclockwise twists. For each of the twenty-six flower buds I examined, the petal twists were oriented the same way: counterclockwise!



ALL IMAGES BERND HEINRICH

Iris pseudacoris *and* Iris versicolor

Iris pseudacoris has a suite of features that are uniformly invariant—e.g. three banner and three flag petals that are universally yellow—but those are expected adaptations. What possible value or difference could budhandedness be—for pollination, for bumblebees, or for anything else—when the feature is obliterated the moment the flower opens? Could the uniformity of the twist be a matter of random chance?

Biology is in large part history, shaped by irrevocable forces and by trifling chance events. Its concern is understanding the distinction between the events that lead to a trait of interest versus the adaptive value of the trait in question. To gain a historic perspective into any specific biological pattern requires seeing where else the phenomenon can and cannot be found. On the other hand, if one considers adaptation, then one can ask if the pattern is associated with any of a large number of environmental factors acting as signals, such as light, temperature, touch, and so on. After answering those questions, one can consider the "how."

Next to my cabin was also a patch of blood iris, *Iris sanguinea*, native to Asia, and in the nearby wetland grew large numbers of the native blue flag, *I. versicolor*. I examined both, sampling twenty-three and fifteen flower buds, respectively. The results were identical: the twist of the petals in the flower buds was 100% counterclockwise, suggesting that this odd trait was perhaps traceable to iris ancestors. Comparison with other species was necessary to see if the trait could be traced to more distant forebears.

Both scarlet runner beans (*Phaseolus cocaineus*) on poles along our garden fence and common morning glories (*Ipomoea purpurea*) in our field have climbing vines. A vine has four options: spiral either clockwise or counterclockwise in response to some feature of the substrate, go straight up, or twist willy-nilly. The sixteen runner beans I examined wound their way up everything they encountered—fence, grass stems, bushes, goldenrod, each other—all twirling counterclockwise. The signal for the winding was contact; when the growing vine tips were unobstructed they went

straight. Of the seventy morning glories sampled, all, without exception, twisted counterclockwise. And fifty nightshade vines (*Solanum dulcamara*) at another site proved to be uniformly twirled counterclockwise.

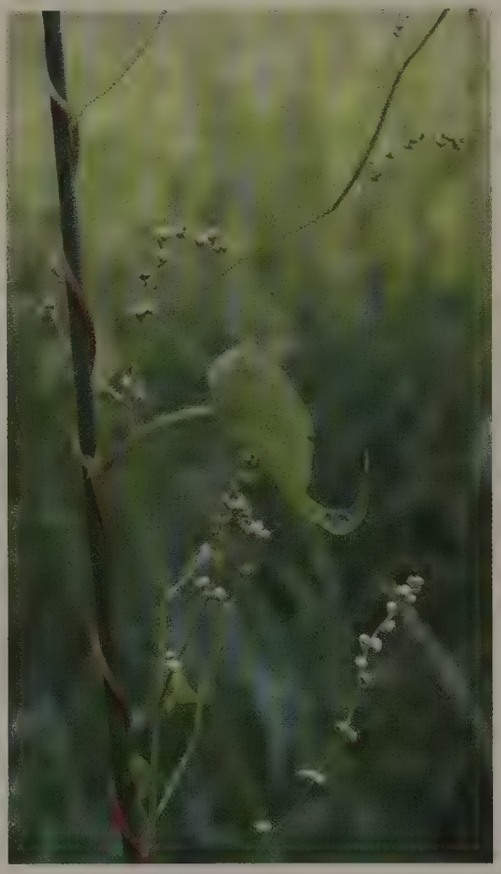
Unanimity in twist direction—supposedly a neutral trait—in 236 individuals of four different plant families, Iridaceae, Fabaceae, Convolvulaceae, and Solanaceae, seemed odd, unless they shared a common ancestor. But why did that ancestor have that characteristic, and why did modern descendants retain it? In these four plant families, the twist at least had a function, even though the direction—the point of interest—did not seem to. The functions happened to be flower bud opening in the first, and support for climbing to the light in the other three.

Trees, however, provide their own support. They should have no reason to do the twist—but I decided to check.

I noticed cracks in the dry logs of my cabin walls and ceilings. The cracks ran primarily along the length of the logs, but sometimes they ran at a slant. I made a count: forty-eight logs showed no noticeable cracks running in the slant direction, twenty-seven did and they ran counterclockwise, and only one was clockwise. Trees hoist their leaves on branches to the sunlight with their own trunks. Yet, they were still twisting, as though it was part of their basic make-up.

Why might something as seemingly irrelevant as twist direction have become ingrained? When I Googled "directional movement in plants," I learned that counterclockwise movement by climbing vines was thought to be unique to the Northern Hemisphere (perhaps because it was observed there, or because of the Coriolis effect). If so, then there should be a clockwise twist in the Southern Hemisphere.

The Coriolis effect turns out to be myth. In 2007, Will Edwards, of James Cook University in Cairns, Australia, along with fellow researchers, published their findings that, globally, the direction of plant twists was not affected by locality nor latitude. Two years later, Maria Stolarz, of Maria Curie-Sklodowska University in Lublin, Poland, published her research on the physiological, cellular, and molecular basis of the twirling motion of plants as influenced by light, temperature, and other factors. However, she never mentioned the direction of twisting. Yes, the environment's effect is obviously strong. As I mentioned, in the vines that I had examined, the twirling seemed to occur only in response to contact with vertical objects; otherwise, the growth trajectories were straight.



Bindweed

Suppose the earliest organisms had a specific twist simply by the randomness of the draw due to a common origin, and assume further that it made no difference to their fitness. The logical conclusion from an evolutionary perspective is that anything not needed, such as the specific direction of the twist, would—through endless replication—eventually become abolished, even if it could be carried with little cost. It would be retained in the long run only if it were beneficial. The evidence is ample: the counterclockwise twist was not abolished. It is widely and prominently exhibited. Therefore, it cannot exist now due to random chance. Yet, there is no obvious selective advantage to right versus left as such. Apparently something else besides history and natural selection must operate to maintain it! We must look, I think, to the chemical underpinnings themselves, in the structure of life.

The genetic code is read off one strand of the DNA molecule in one direction, as the double helix unwinds to be copied via messenger RNA. It seems curious, though, that the DNA molecule is not exactly analogous to a zipper. Instead, it is a spiral. Furthermore, the fact that the DNA double helix twists counterclockwise (but is often drawn incorrectly), as does RNA (which is normally single-stranded) when it is crystallized, and the fact that all twenty amino acids in our proteins (as well as in plants) are only of left-handed orientation is also suspect. Why left-handed? All of this is taken as evidence of the idea that all of life on Earth branched from a common ancestor. Indeed. But the conservative nature of evolution aside, I wonder: is there also scope to consider the conservative nature of chemical constraints that may influence the DNA-RNA-protein synthesis machinery?

The handedness of humans, as well as the counterclockwise twist of a vine, are under at least genetic influence, if not control. However, no controlling genes have been identified. By default, we therefore interpret the twist as being controlled by many genes. What if, instead of many genes, it is not genes at all but the nature of the molecules of living things biased toward a *consensus* of mirror images of certain molecules

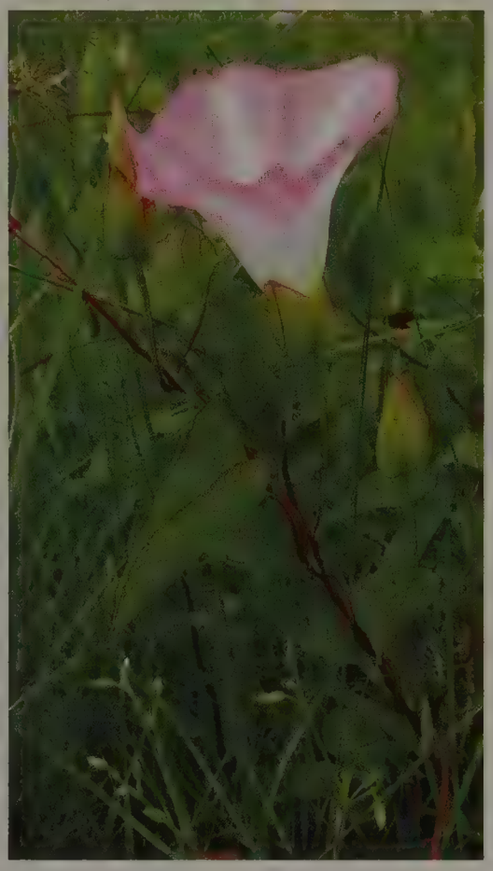
that is required to smoothly operate biochemical machinery and which then have repercussions on overall bio-tissue construction, function, and reproduction? Just as bricks of uniform, rather than random, lengths facilitate building construction, and just as snail shells all twirl in the same direction because the odd ones can't mate, perhaps our molecular building blocks restrict our features to a certain directionality for optimal growth and function.

This view does not mean that chance and history had no role to play in the evolution of the twist. Perhaps a mere twist—any twist—in the chain of molecules was favored for a biomechanical advantage in the first molecules of life. It may have provided momentum for the reactions and an increase in efficiency—especially if there was a consistent twist in a specific direction that in turn translated to a bias in the orientation of the amino acids being accepted into the growing amino acid chain. Experiments might tell, but the DNA we have now is all we have to go on.

Whenever we "make" DNA, we copy it off existing strands—we replicate a 3.4-billion-year-old script. This DNA has been edited all along, and from all that editing, we can't be sure whether or not there has been mechanical advantage involved in which and how specific macromolecules fit together, or where there was perhaps slightly more compatibility with those that ended up in coding mechanisms—similar to how the ruts of a well-travelled road bias travel paths, or how cars have been made with the wheel span of existing roads.

As far as I know, we cannot yet make an artificial DNA molecule twist in the opposite direction, to then present it with a choice of right– and left-handed amino acids, to see if the protein made would then preferentially incorporate amino acids of one direction or the other. If we could then feed this new protein to an iris plant or a vine, we might watch with rapt attention to see if the twist then changes to the opposite direction.

If we were to synthesize amino acids in a test tube, we would get an equal number facing both directions, but the proteins of all plants and animals consist almost exclusively of the left, mirror image of the molecule. We're composed of billions of these molecules and they all face one direction. The twist of the two strands that make up the DNA molecule happens to be counterclockwise. Perhaps on some other planet it is clockwise.



Morning glory

The commonness of the counterclockwise twist in the ultimate product, the plant body, started me down a long rambling road with many twists and turns—from the microscopic to the cosmic—until I acquired one more data point. Or perhaps it was fifty-six points. Ironically, it was a weed in our garden that eased my mind considerably (though by no means completely). I thank my lucky stars for this weed, and for my penchant to always try to get a second opinion, or better yet, another fact.

Black bindweed, *Polygonum convolvulus,* is a creeping-climbing weed with leaves and vines and associated habits of growth that seem nearly identical to those of the morning glory. They are currently placed in two different plant families, Polygonaceae and Convolvulacea. Bindweed flowers are tiny and white, and the plant is not in the least eye-catching. But after I saw one draped over a blueberry bush and was pulling it off, I suddenly realized its potential.

Like the morning glory, the bindweed sends runners in straight lines in all directions, and here and there, where it contacts a bush or a grass stalk, it sends a tendril curling its way up to display its flowers. My *Polygonum* specimen appeared to twirl exactly like the morning glory. I photographed the two side-by-side to show the identical plant strategy. But when I unwound the bindweed vine from the goldenrod stalk it had climbed, I needed to turn it counterclockwise. It had been wound *clockwise*! I looked again, again, and again. And then I pulled up every one I could find, fifty-six to be exact. Every single one was wound up clockwise. To be absolutely sure I had not been wrong before, I revisited the morning glories, and the beans, and brought a couple dozen of them in to spread on my desk, to compare them side-by-side. There was no doubting the difference in the directions of the twirls.

I was grateful indeed that this little weed saved me from grand delusions. Nevertheless, the wonder of the 236 individuals of four plant families agreeing on such a trivial point as the direction of the twist is compelling, even though how they ended up that way remains unanswered.

Bernd Heinrich is a biology professor emeritus at the University of Vermont. He has published numerous books, most recently The Homing Instinct: Meaning and Mystery in Animal Migration *(Houghton Mifflin Harcourt Publishing Company, 2014).*

ON THE ROAD AGAIN

The Lincoln Highway persists in

The abandoned State Line Gas Station stands at the border of Nebraska and Wyoming on the Lincoln Highway (US-30). Several old gas pumps and various derelict vehicles remain at the site.

For almost two hundred years, Americans have been fascinated by the notion of tying one coast to the other. Whether through national land acquisition, the building of transcontinental institutions that made travel or communication easier, or through individual journeys, we have been fixed on the idea of spanning the continent. The excitement started in the dawning years of the nineteenth century with the Louisiana Purchase and the Lewis and Clark expedition, and was a part of national pride by the time California was admitted to statehood in 1850. By then the nation's land holdings had filled in most of what makes up the lower forty-eight states today. The nation had tripled in size in fifty years, and Americans who had looked westward from Kentucky suddenly found themselves standing on the far coast and looking westward out over the Pacific.

The first continental crossing by automobile came in 1903. That embryonic year also saw the incorporation of the Ford Motor Company and the first flight by the Wright brothers. About the middle of May, a Vermont physician accepted a challenge to drive an automobile from San Francisco to New York. Dr. H. Nelson Jackson never got rich from winning the bet; the stakes were but fifty dollars. He hired Sewell K. Croker as his mechanic, and on his advice bought and equipped a used twenty-horsepower, two-seat, open-top Winton. On May 23, four days after making the bet, they left for the East. Near Caldwell, Idaho, the pair adopted a stray bull terrier whom they named Bud. Following their own example, Jackson and Croker provided their new companion with driving goggles to protect his eyes from

spirit if not intact.

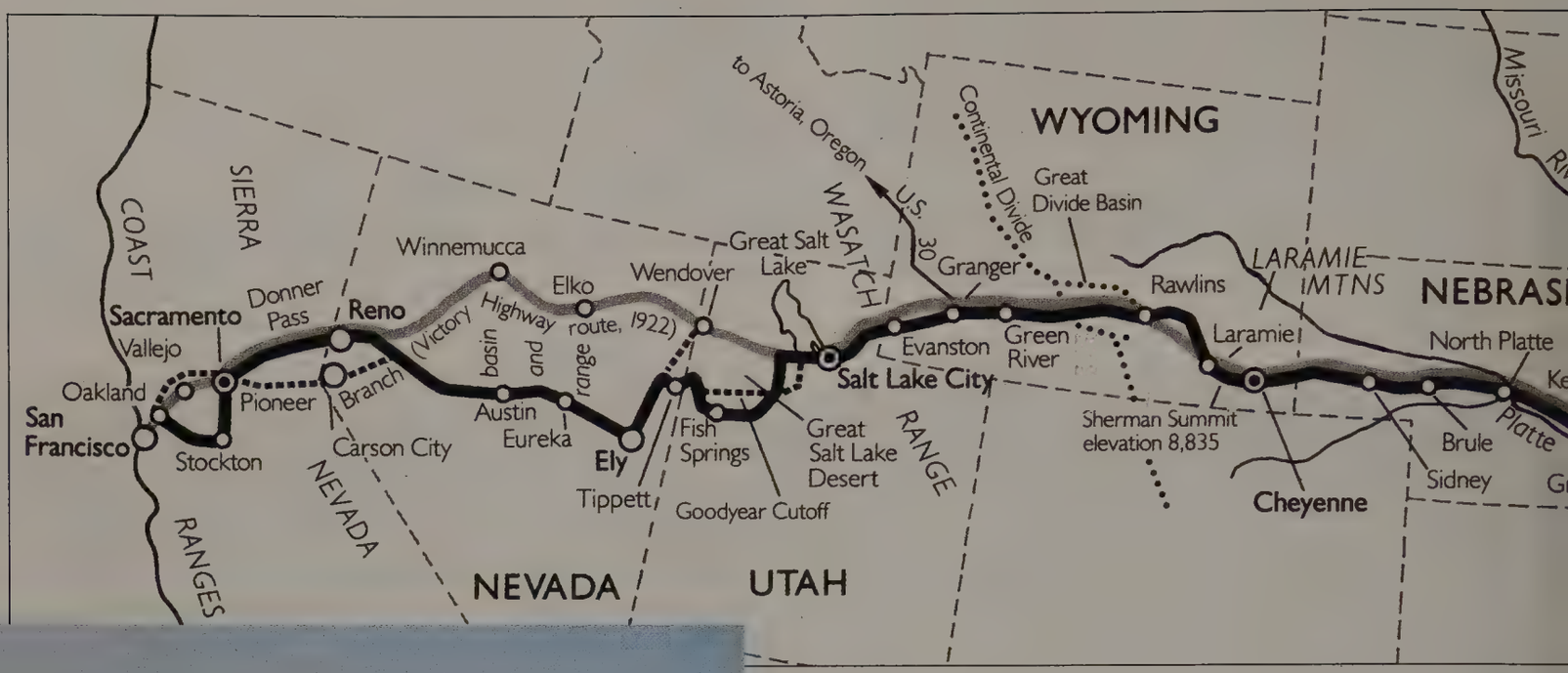
ORIGINAL TEXT AND PHOTOGRAPHS
BY DRAKE HOKANSON

WITH RECENT IMAGES AND
COMMENTARY BY ELLIOT OFSOWITZ

flying mud and blinding dust.

The trio traveled some six thousand hard miles and arrived in New York City in the wee hours of July 26, sixty-five days after leaving San Francisco. In all, they spent some three weeks of the time repairing the car, resting, or waiting for parts. About half the distance Jackson and Croker traveled would ten years hence become America's first transcontinental highway. Up until September 1912, very few people had ever seriously considered driving an automobile across the country. But during that month

Mrs. Joseph DeHart sold cut flowers at her home in Lancaster, Pennsylvania, where Lincoln Highway travelers once stayed the night.

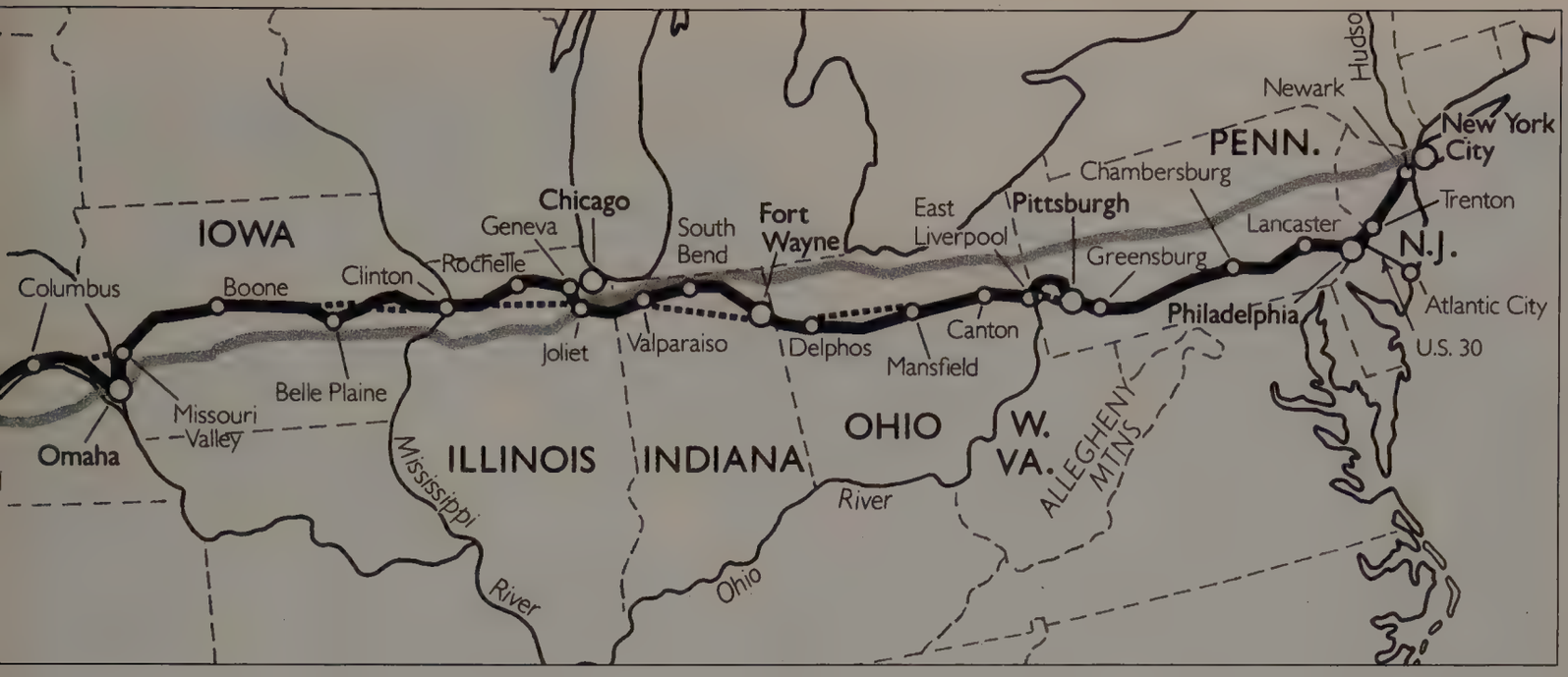


Carl Graham Fisher hatched a new idea that would help change how America traveled.

Fisher was a man of big ideas. His Indianapolis Motor Speedway had become a smashing success, especially after he paved it with brick and inaugurated the Indianapolis 500 in 1911. He was founder of the Prest-O-Lite Company, maker of carbide headlights, which in the days before the all-electric car provided the only reliable light for night driving. He was an athlete, a keen lover of yachting and ballooning, and never one to pass up a good promotional idea. In 1908, as a publicity stunt, he attached a Stoddard-Dayton auto to a helium balloon and floated across Indianapolis. He had been a bicycle salesman and racer, and later turned to racing automobiles, at which he broke a few world records and raced against the famed cigar-chomping Barney Oldfield. Later in life he would be the founder and promoter of one of the biggest land developments in the country: Miami Beach, Florida.

But in the early fall of 1912, Fisher's old ideas, now successful on their own, must have seemed a little stale,

Above, West of Omaha, Nebraska, this section of the Lincoln Highway in Elkhorn is one of only twenty miles that were paved with brick in Nebraska. It is one of the most well-preserved brick-paved sections in the country. The roadway was listed on the National Register of Historic Places in 1984. Right, *Original 1914 Lincoln Highway concrete paving remains intact on Sisley Road near Newcastle, California.*



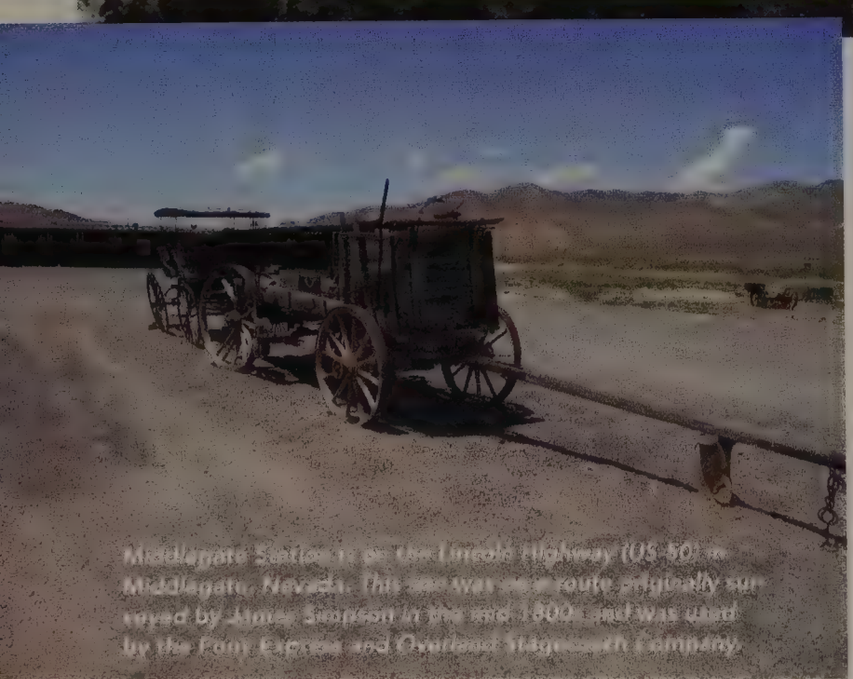
and he had a new scheme. He was restless, full of wanderlust; but instead of dreaming about making a trip himself, he dreamed of making a road to enable travel.

His new idea was called the Coast-to-Coast Rock Highway. Realizing that the success of any idea depended a great deal on rousing the enthusiasm of others, he disclosed the plan to anyone who would listen. In early September of 1912, he threw a large dinner party for the leaders of Indianapolis automobile manufacturing. Fisher knew that the enthusiasm and capital of these men could get this highway started. After dinner at the Deutsches Haus, he spoke of the need for good roads and laid out his plan. "A road across the United States!" Fisher shouted to the group. "Let's build it before we're too old to enjoy it!"

He told them that a graveled highway could be built from coast to coast for about ten million dollars, a low figure even for 1912. This money would be used to buy only basic road-building materials; the labor and machinery, he said, would be provided by the counties, towns, and cities along the yet undetermined route. What community could turn down the opportunity of free materials and a place on the map astride America's first transcontinental highway? In addition, Fisher wanted this dream highway finished in time for twenty-five thousand cars to cross the continent for the Panama-Pacific International Exposition only two and one half years away. By the time of his highway idea, Fisher had made his millions, though he would later lose them in Florida. He was intent on seeing this highway built not to earn him money, nor to gain attention for himself, but because he felt the nation needed it.

Because it was the venue of the exposition, San Francisco would be the western terminus for the highway, and there was little doubt that America's great metropolis, New York City, would be the logical site for the eastern end. Fisher would not divulge any details about the route between these points; in fact, no route had been selected or even considered. He first wanted to build support for the road as an endeavor for the nation as a whole, not just a project of the states and towns along the route. A committee would be appointed later to research and determine the exact route.

Tama County, Iowa, in the 1980s



Middlegate Station is on the Lincoln Highway (US-50) in Middlegate, Nevada. This section was a route originally surveyed by Howard Stephen in the mid-1800s and was used by the Pony Express and Overland Stagecoach Company.

Here was an idea whose time had come. The automobile was well established by 1912, but good roads were not. Close to 500,000 motor vehicles were registered in the U.S. by 1910. Those vehicles plied the streets and roads during good weather but spent the winter and wet seasons up on blocks in the garage. People were beginning to look hard at the motortruck for moving goods; it was already beginning to displace horses and wagons for city deliveries. Auto drivers were becoming more adventurous as their machines became more reliable. A few hardy souls had even driven clear across the continent by automobile, and anybody who had spent much time behind the wheel was complaining about the roads.

The motorists of 1912 had some two and a half million miles of road to drive, but less than seven percent was improved in any fashion. Improvement usually meant some grading or graveled macadam; oiled macadam or

asphalt would come later. A few hundred miles of brick was the extent of the hard paving, because concrete was as yet virtually unknown as a road material. Most of the roads across the nation were just plain dirt. To make matters worse, most of these roads didn't really go anywhere. There was nothing resembling a system of roads; instead most roads extended outward from rail centers, where they served to bring the farmer into town with his goods. They resembled the spokes of a wheel, radiating from towns of importance, with no attempt to connect the roads of one area with another. The farmer did the best he could between the farm and the county seat, but when he wanted to go to the next town down the line, he rode the train.

Road building and maintenance were entirely the province of local government, and "working off the road tax" was a term that suggested leaning idly on the handle of a shovel. There were no federal funds for roads in those years, and the tiny state and county appropriations were said to be wasted on "pork barrel" projects that had little effect on the condition of roads. "The highways of America," Fisher wrote to a friend, "are built chiefly of politics, whereas the proper material is crushed rock or concrete." In fact, twenty states had no road departments of any sort. The long-distance motorist of 1912 was a pathfinder in every sense of the word. Gulf Oil wouldn't introduce the free gas-station road map until the following year, and guides existed only for the eastern states. Stopping for local advice was of limited help. Motorists found that they had to stop every few miles to ask directions; a farmer or resident seldom had any knowledge of the roads beyond a fifteen-mile radius.

Carl Fisher was not the first to propose a transcontinental highway (the American Automobile Association had suggested one as early as 1902), but he was the first to propose a road with a real improvement plan and the means to finance it. Other routes were drawn on some maps, but they were for the most part unmarked, unimproved, and of scant transportation value. A few months prior to Fisher's announcement of his Coast-to-Coast Rock Highway, a group of promoters had left Los Angeles in an automobile headed east to plot a route between the coasts. They sought to raise money from towns along the way for basic improvement.

But Fisher had bigger ideas: he had his sights set on targets where money for a real highway could be raised. Late in October of 1912, Fisher published an Ocean-to-Ocean Highway Bulletin, a publication listing contributors and intended to generate enthusiasm for the project. On the cover Fisher had placed a tantalizing map of the United States depicting several of the phantom trails of mud that crossed the country—the Northwest Trail, the Sunset Trail, and others—but had intentionally drawn no clues as to where his grand highway might run.

A restored Ford Model A pickup truck is parked in front of the Banta Inn in Banta, California. Originally built as a two-story saloon / sporting house in 1879, the inn has continued as a saloon to this day. The original route of the Lincoln Highway went directly past the front of the Inn.

With the enthusiasm of the Indianapolis automobile manufacturers behind him, Fisher began his campaign in earnest. He wrote letters, sent telegrams, and paid personal visits to representatives of the automobile trades across the United States. It was clear to Fisher and to the men of the infant auto industry that the success of the motorcar lay not only in better automobiles but in better roads as well. For the first time, manufacturers found that they could produce more cars than the market could absorb. The public, while ever more excited about the new-model cars, was seeing a real limit to the usefulness of even the best machines on roads that were clouds of dust in dry weather and rivers of mud when it rained. If the public were to see a clear trend toward highway improvement, it might stimulate sales and advance the cause of the automobile everywhere.

Within thirty days of the announcement of the Coast-to-Coast Rock Highway, Fisher had a million dollars in pledges and considerable ink in the nation's press. Industry pledges and smaller donations increased as word of the new highway spread during the early months of the campaign. Newspapers and magazines wrote Fisher

asking for articles. New-car orders were even being conditioned upon completion of the highway in time for the exposition. Communities across the country wondered if they would be selected to be on the route.

Carl Fisher knew that the support of Henry Ford was essential to the success of the ten-million-dollar road fund. By 1912, the 118,000 Model Ts already on the road had made the Ford Motor Company the largest in the country. Three quarters of the cars then in use were Fords. Henry Ford was already an American hero, the young mechanic from Michigan who, with limitless drive and keen automotive sense, had thrown his weight behind his ideas and risen to the top of the manufacturing world. Ford was also idiosyncratic and stubborn to the extreme, and inclined to resist anything that the rest of the automobile industry thought was a good idea.

Abandoned Lincoln Highway near Robinson Summit, Nevada

Ford's millions could build a fair portion of the highway, but more important would be his goodwill toward this new project. Many manufacturers were waiting to see what Ford would do before throwing their support behind the Fisher road. If Henry Ford thought it was a good idea, then the whole world would stand behind it. Fisher fanned the flames of national enthusiasm and laid his groundwork carefully before approaching the cantankerous automaker.

Fisher made his move early in the campaign, and a reply was quick in coming. James Couzens, secretary and treasurer of the Ford company, wrote expressing the attitude of Mr. Ford:

"Frankly the writer is not very favorably disposed to the plan, because as long as private interests are willing to build good roads for the general public, the general public will not be very much interested in building good roads for itself. I believe in spending money to educate the public to the necessity of building good roads, and let everybody contribute their share in proper taxes."

It must have been clear to Fisher that the Ford refusal put the ten-million-dollar fund drive in serious jeopardy. There simply wouldn't be money or time to build the Coast-to-Coast Rock Highway soon enough to take autoists to the Panama-Pacific International Exposition. But Carl Fisher would not give up. The country was now excited about this "dream road," and for the first time many people imagined themselves driving their own automobiles from one coast to the other. Contributions, though small, continued to arrive. Another way needed to be found to make this highway a reality.

Early in December of 1912, Fisher received a note that was to have a great effect on the Coast-to-Coast Rock Highway. The letter offered a $150,000 pledge to the Fisher project, but, more important, it contained an idea that was to engrave this highway in the public imagination for years to come. The letter was from Henry B. Joy, president of Packard Motor Car Company.

"I think your Good Roads Committee, who is working up the ten million dollar fund, ought to get up a protest to Congress on the expenditure of $1,700,000 in a monument in Washington to Abraham Lincoln." Instead of the marble monument that Congress was planning, Joy wanted to see Lincoln memorialized for "... the good of all the people in good roads. Let good roads be built in the name of Lincoln." Less than a year old when Lincoln was shot, Henry Joy looked to Abraham Lincoln as a larger-than-life hero. Joy's father had known Lincoln and had been a great supporter of his campaign and ideals. The honorable ghost of the martyred president had hovered close during Henry Joy's childhood,

LINCOLNHIGHWAYASSOC.ORG

With the advent of the federal Uniform System of numbered highways in 1925, the original Lincoln Highway Association had promoted itself out of a job. Realizing that they had succeeded in their mission to begin a transcontinental network of highways, the Association voted, on November 11, 1927, to cease its "active and aggressive" operations as of December 31, 1927. In 1992 a new Lincoln Highway Association was formed to identify, preserve, and improve access to the Lincoln Highway; to prevent further deterioration, destruction or alteration of the remaining sections of the road; and to educate the public about the Lincoln Highway and its history. Visit the Lincoln Highway Association Website at www.lincolnhighwayassoc.org/ to see an online interactive map, showing three generations of the entire Lincoln Highway. *E.O.*

instilling in him the admiration that his father had felt.

The last sentence of Joy's note caught Fisher's attention. He had been looking for a better name for this new highway. The Coast-to-Coast Rock Highway could hardly be called inspiring. He had toyed with the idea of the Ocean-to-Ocean Highway, but that, too, was pretty dull. A friend in Congress suggested that the plan would be enhanced by including some patriotic appeal in the title or routing. Someone had suggested the American Road, and that wasn't right. But Lincoln—that might just be something. He was the great hero to Americans north of the Mason-Dixon line, and the name would have profound patriotic appeal.

Carl Fisher was quick to grasp the value of the name Lincoln, and equally quick to approach Joy in hopes of involving him directly in the cause. Fisher's enlistment of Joy was a wise move. Detroit was fast becoming the center of the auto industry, and Joy was among the city's top capitalists.

During the spring of 1913, Fisher hurriedly called several informal and closed meetings in Detroit, where he assembled several men who would soon be the power behind this highway. The assembled men knew of the Ford refusal, but all remained optimistic, or at least hopeful, that the money could be raised. Fisher's enthusiasm pushed aside any hint of misgivings concerning the road fund. Smaller amounts were coming in from across the country.

On July 1, 1913, the group met again. They decided on the name Lincoln Highway for their yet unrouted road and swiftly completed the legal formalities of incorporation as the Lincoln Highway Association. They then elected the first slate of officers, who took their new task to heart and proclaimed their purpose: "To procure the establishment of a continuous improved highway from the Atlantic to the Pacific, open to lawful traffic of all description without toll charges: such highway to be known, in memory of Abraham Lincoln, as The Lincoln Highway."

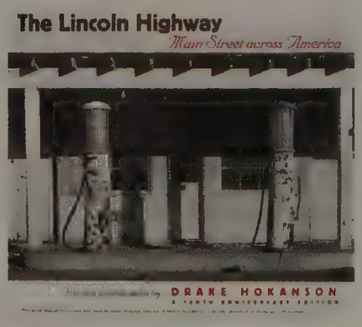
All they needed now was a route.

Armed with everything they could find, the directors of the association set about making their decision. They assembled all available guides and maps, and the volumes of notes kept by Joy on as many as ten cross-country trips over various routes. So little published road information was available that the group often had to rely on railroad timetables to provide mileages between cities. After evaluating the road condition of many routes, figuring many possible mileages, and listening to much firsthand experience, and after what must have been considerable argument and deliberation, the route was chosen.

At the encouragement of the association, civic groups, business people, and general citizenry from communities along the route fanned out to paint official Lincoln Highway markers in patriotic red, white, and blue stripes on barns, trees, rocks, telephone poles, and fenceposts.

The first seedling mile was completed near De Kalb, Illinois, in the fall of 1914. The next year, 1915, saw four seedling miles built on the highway. The Lincoln Highway Association was shrewd in seeing that these miles of road were generally located in the countryside, far from town limits so as to provide the greatest contrast possible between unimproved dirt and smooth concrete. This also allowed the seedlings to grow in either direction.

The successful publicity of the Lincoln Highway project fueled a great surge of highway fever in the United States. The country saw what was planned along the Lincoln Highway, and people everywhere had to have their own highways.



Excerpts from *Lincoln Highway: Main Street across America, a Tenth Anniversary Edition* © 1999 by Drake Hokanson. Used with permission by University of Iowa Press.

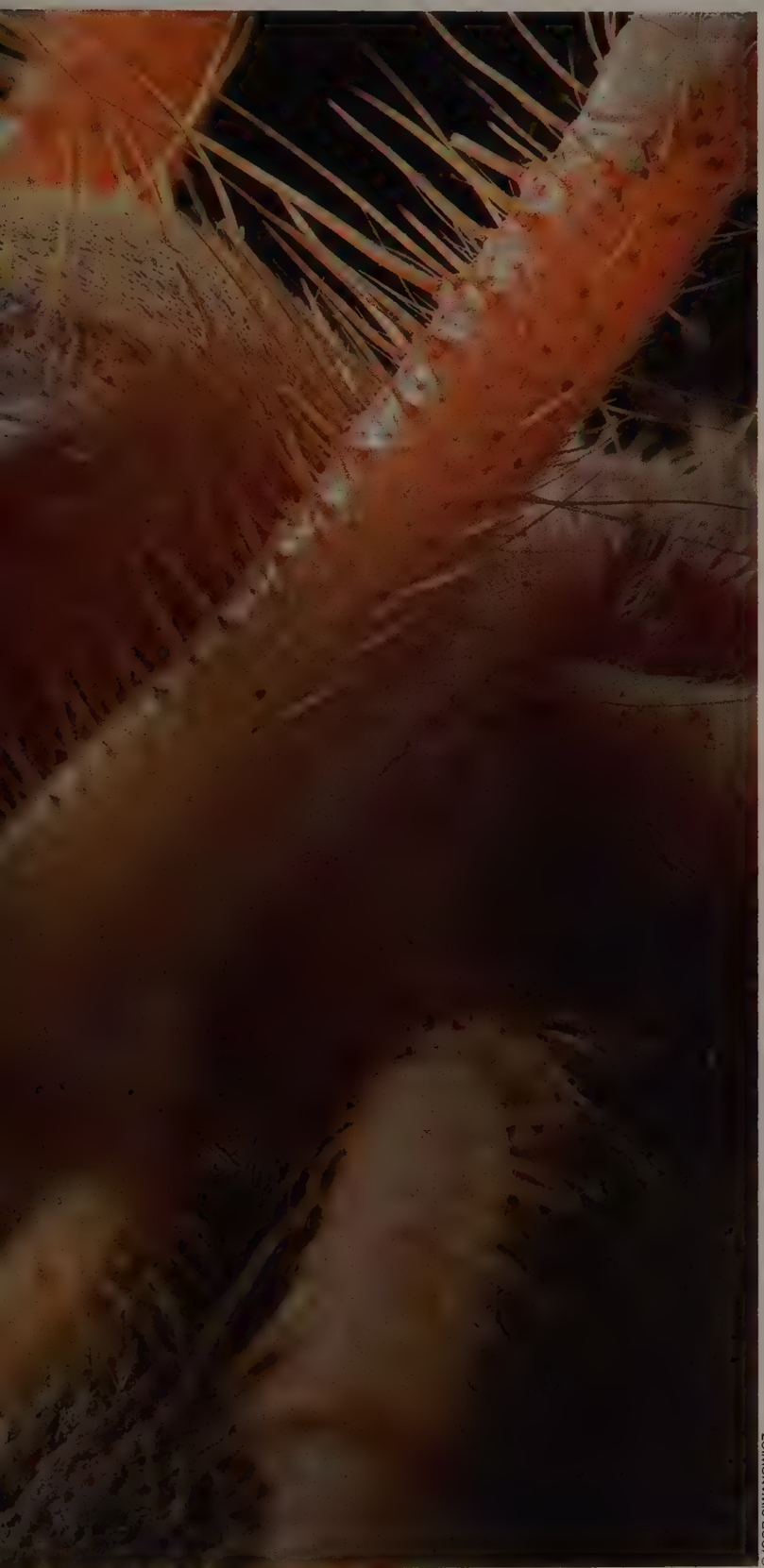
Drake Hokanson, photographer and writer, is professor emeritus at Winona State University, Winona, MN. He is also the author of *Reflecting a Prairie Town: A Year in Peterson* (UI Press, 1994). Retired from a career in information technology and living in Florida, **Elliot Ofsowitz** volunteers as the technical advisor to *Natural History.* As Life Members of the Lincoln Highway Association, Elliot and his wife have toured the Lincoln Highway from New York to San Francisco over the last three years.

THE NAMING OF PARTS

BY THARINA BIRD

A visual atlas of solifuge jaws enables research on these poorly-understood arachnids.

IMAGINE A SPIDER-LIKE ANIMAL, with jaws up to a third the length of its body that runs so quickly and erratically that the human eye easily mistakes it for a seed blowing in the wind. Such creatures exist all over the world in dry environments including the savannas, steppes, and deserts, of Africa, the Middle East, central Asia, the southwestern United States, Mexico, and South America. Termed solifuges, but also known as camel spiders, sun spiders, wind scorpions, or baardskeerders (beard-cutters), these arachnids form a separate order from spiders and scorpions. Unlike most of their arachnid counterparts, solifuges carry no venom and are basically harmless, belying urban legends claiming otherwise. Members of the order Solifugae have several unique features, such as the racquet-shaped sensory organs on their hind legs that detect vibrations or chemical cues. Their most prominent characteristics are their oversized jaws, called chelicerae. However, until my colleagues and I embarked on a ten-year project to survey these fascinating arachnids, no comprehensive overview of solifuge jaw morphology existed.



© IGOR SIWANOWICZ

This arachnid, Galeodes *sp., is one of about 1,100 species in the order Solifugae.*

Solifuges are challenging to study. Most avoid sunlight (indeed, the Latin term "Solifugae" means "those that flee from the sun"). Many species are solely nocturnal. Others come out only during the daytime, usually during the hottest time of the day, sometimes higher than 35°C in deserts. When they do emerge, they move quickly, at speeds up to ten miles per hour. Larger species may measure 15 centimeters long and are easier to spot, but the small species—some only a few millimeters long—are often overlooked. They are also seasonal, abundant only in warm weather, and their lifespans are brief. Finally, their chosen homes are not conducive to research; these hot, dry places tend to be dangerous for humans and pose many logistical challenges.

Despite these hurdles, a smattering of adventurous naturalists over the years have collected and written about roughly 1,100 solifuge species. Unfortunately, these efforts have not been coordinated, and each discoverer has honed in on different characteristics of their specimens, using their own terms to describe their observations. At times the terminology has even been contradictory. For example, some adult male solifuges have two flagellar structures on their jaws, an upper and a lower. Some scientists have used the word "flagellum" to refer to the upper structure, some to the lower structure, and others to both structures together. Multiply such inconsistencies by the number of different features on these complex arachnids, and the confusion quickly escalates. Without a common language, it can become impossible to classify an individual specimen as belonging to one species or another. Lacking this basic starting point, more in-depth studies of solifuge biology cannot proceed.

To address this problem, my colleagues and I set out to define and catalog the different parts and protrusions of solifuge jaws. The jaws have a variety of functions: capturing prey, feeding, fighting, defending, burrowing, mating, and producing sound. Within each of these categories, the jaws may play several roles. For instance, in mating, the

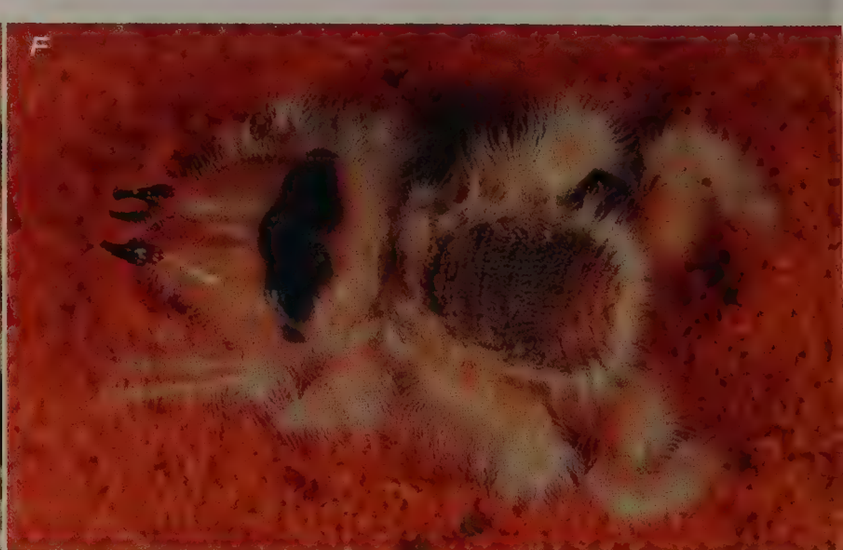
jaws might subdue or hold a struggling female, prepare the female for mating, or transfer sperm to the female. In order to serve this wide array of functions, the jaws contain an unusually high concentration of distinctive features, and are therefore the most important section of solifuges' bodies to be used for their classification.

There is also a clear division between the main function of the jaws in females and males. Females mainly use the jaws for feeding, crushing their prey to a liquid mush they can suck up. Males also use the jaws for feeding, but they tend to eat less than females and do not live as long. With few exceptions, solifuges are generalist predators. Jaws of different species are thus similarly adapted for feeding, and tend to be similar between females of different species. Mating behavior, on the other hand, is more species-specific and most modifications of the jaws are therefore apparent in the males. Hence features of adult male solifuge jaws are crucial for species identification.

When trying to decide whether structures on different individuals and species are the same or different, scrutinizing actual specimens—rather than reproductions—is necessary to assess the structures' size and exact position. For our study, we thus needed specimens representative of the major taxonomic groups within the order. We chose Southern Africa as our starting point: globally, it has the highest diversity of solifuges per land area, and the largest scientific collection of solifuges in the world is curated at the National Museum of Namibia. We also went on several expeditions to observe and collect solifuges in such places as Israel, in the harsh climate near the Dead Sea, and in Kazakhstan, where co-author Lorenzo Prendini was stung by a highly venomous buthid scorpion. We scoured the collections of sixteen major museums and scientific institutions across the United States and in Israel, Turkey, France, Belgium, South Africa, Namibia, Germany, and Sweden. We were able to examine 510 specimens representing 188 species with examples from each of the twelve solifuge families, and major taxonomic groupings therein. Additionally, we reviewed roughly 700 publications in English, German, Spanish, French, Italian, Russian, and even Latin, discussing solifuge morphology, systematics, and behavior, going back to the late 1700s.

Using these resources, we developed a dictionary of nearly eighty terms with accompanying images to describe the different parts of solifuge jaws. Structures with similar appearance and position on different specimens were given the same name. Our hope is that all current and future researchers will use these terms as a common

© ALEXANDER GROMOV (A, B), SIMON VAN NOORT (C), SANJAY DAS (D), TELANÉ GREYLING (E), CHRISTIAN BOIX-HINZEN (F), THARINA BIRD (G, H)



Examples of the variety of arachnids in the order Solifugae: A. (female) and B. (male) Galeodes caspius fuscus, *Kazakhstan;* C. Rhagodes *sp., Kenya;* D. Rhagodes *sp., India;* E. Hexisopus sp., *Namibia;* F. Chelypus *sp., South Africa;* G. Metasolpuga picta, *Namibia;* H. Zeria sericea, *Namibia.*

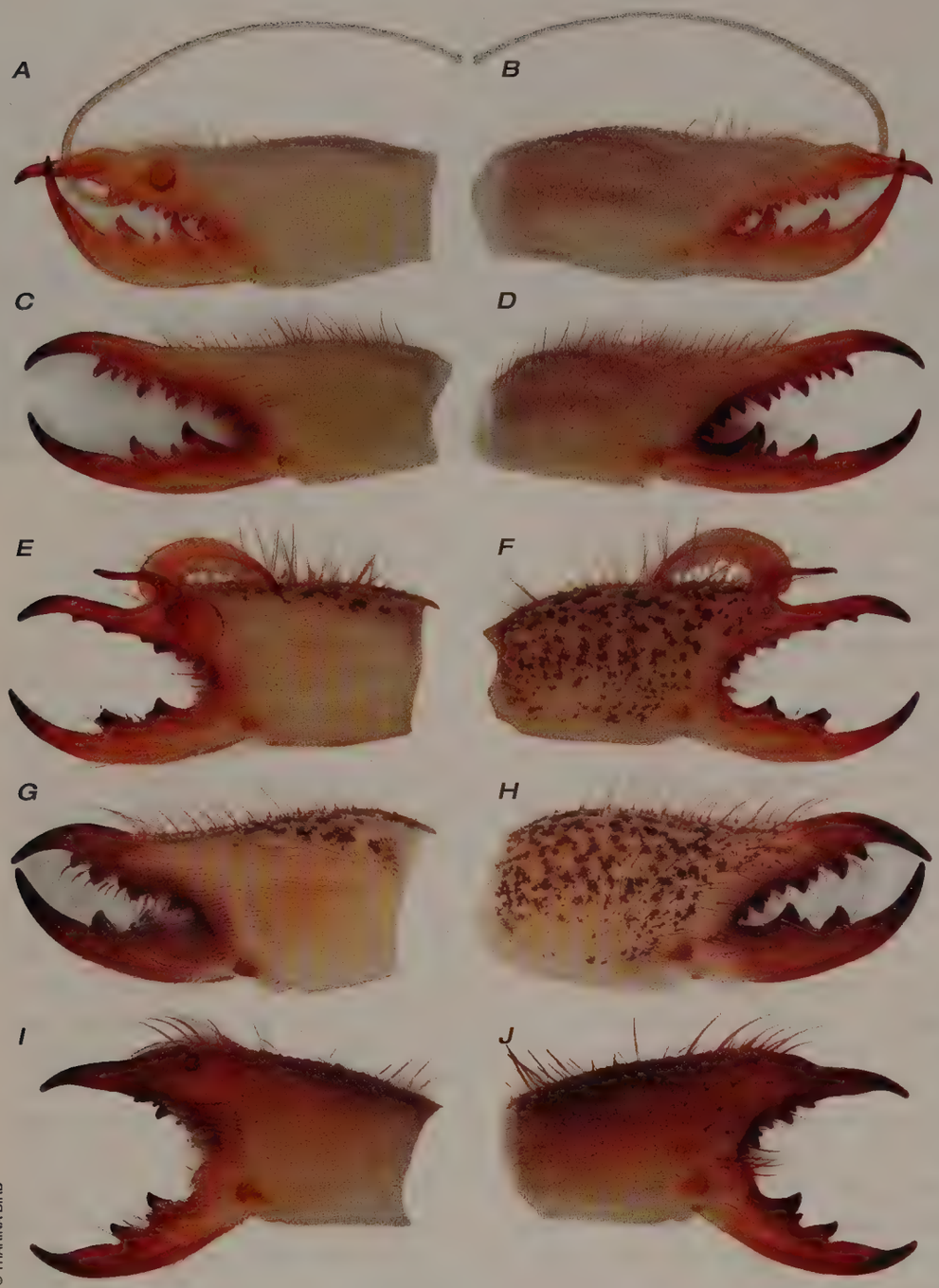
language when writing and speaking about solifuges.

Some of the terms we set forth were already in use. For example, most recent scientists agreed upon the general term "cheliceral fingers" to refer to the opposing sections on the far end of the jaws on which the teeth are situated. But we also chose a single appropriate term for structures that went by various names. For instance, the mucron—the usually toothless far sections of the cheliceral fingers—has previously been called the terminal fang, "toothless terminal portion" of the jaw, and untoothed finger.

Moreover, we identified several new structures that have never before been described. We named one such structure the mucron organ, which is a small, round structure, paler than the surrounding cuticle that appears on the mucron of the jaw. While we observed the mucron organ on many species, its purpose is not known. We also found larger round-to-oval depressions situated in the lower part of the jaws. Although visible in various published images of solifuge jaws, they have been readily dismissed as slight abnormalities in the surface of the cuticle, or perhaps as cuticular damage. Only after looking at many specimens did we appreciate that these "irregularities" were fairly consistent. We hence referred to them as the medioventral organ, but, as with the mucron organ, their function remains unknown.

Beyond streamlining the terminology for parts of the jaw and identifying new structures, we proposed novel hypotheses about functions of known structures. For example, mole solifuges belong to a small, burrowing family of solifuges found only in southern Africa. Their unique morphology is clearly associated with their behavior of "swimming through the sand." All male mole solifuges have a structure on each jaw that we termed the "prolateral dental process." Previously interpreted simply as a tooth, this structure hampers or prevents another important structure, the flagellum, from rotating past a certain point when manipulated, thus functioning as some kind of stopper to flagellar movement. Such a stopping mechanism can be very useful in preventing damage to the flagellum during burrowing.

We also drew novel conclusions about the evolution and behavior of solifuges. For instance, each of the two jaws present in a solifuge contains a smooth area, often with well-defined ridges. These areas on the inner sides



© THARINA BIRD

The jaws of solifuges in the family Daesiidae. Prolateral ("inner") side in left column; retrolateral ("outer") side in right column. Note males with flagellum, females without. A–D: Namibesia pallida, *male with typical whiplike flagellum (A, B) and female (C, D). E–H:* Ammotrechelis goetschi, *male with broad whiplike flagellum and bowl-shaped base (E, F) and female (G, H). I, J:* Gluvia dorsalis, *male with membranous, bowl-shaped flagellum.*

of the jaws are known as the stridulatory apparatus; when rubbed together, they produce a sound, which seems to be amplified in some species by modified hairs associated with these areas. The function of this sound—and whether the stridulatory apparatus plays a role other than noise-making—has been unclear. Based on our review of the literature, we believe the stridulatory apparatus serves two roles. The first is in chewing. Prey can be crushed between the ridges of the stridulatory apparatus. Female solifuges eat more than males, and the stridulatory apparatus tends to be more prominent in females than males, supporting its use in chewing. The second role is to produce sound for defensive purposes. For example, solifuges may imitate the sound of other, more dangerous species with whom they share a habitat, such as vipers. These dual functions raise the question of which evolved first: did a chewing apparatus later become useful for defense, or did a defensive apparatus become useful for chewing? At this point, we don't have enough information to say, but we have laid the foundation for testing these hypotheses in future research.

One evolutionary question we *were* able to answer concerns the origins of the flagellum, an appendage on the inside of the jaw of adult male solifuges. Its appearance varies widely across species. A partly rotatable, spoon-shaped flagellum is characteristic of the family Galeodidae, found from North Africa to central Asia. The similarly distributed but more robust, short-legged Rhagodidae have two flagella which overlap in such a manner that they form a half-moon-shaped tube.

A typical whip-like flagellum is long and slender; depending on the family, this type of flagellum is either fixed immovably to the jaw (as in the largely African family Solpugidae) or is able to make a half-circle rotation around an axis at the base of the flagellum. Even within the Solpugidae, what seem to be secondary modifications include, for example, the claw-like flagellum typical of one of its genera. Irrespective of these modifications, all whip-like flagella are unified by the presence of two canals that run along the length of the shaft of the flagellum: one blind-ended canal that seems to connect to the hemolymph in the jaw and which might function to extend or rotate the flagellum, and a second canal containing a fluid of unknown function and which opens to the outside at the apex of the flagellum.

Some flagella are membranous, such as the non-rotatable bowl-shaped flagellum of the New World family Ammotrechidae, or the rotatable flagellum varying from husk- to bowl-shaped in most Daesiidae, a speciose family with a wide distribution in both Old and New World continents. In other families, such as the North American family Eremobatidae and the southern African fam-

ily Melanoblossiidae, the flagellum is less distinctive and strongly resembles the setae, or stiff bristles, from which it is presumed to have evolved. This diversity makes it seem plausible that different species' flagella are not in fact the same structure, and could have evolved from multiple distinct origins.

Rather than looking at all species as a group and seeing only the diversity of flagella, we considered species one by one and noticed strong similarities between flagella structure and position on pairs of species. This approach enabled us to line up all the species such that the flagellum changed very little from one species to its neighbor. For example, the two seemingly disparate categories of a whip-like and a bowl-shaped flagellum are bridged by the unique flagellum of the daesiid *Ammotrechelis*. This species' flagellum comprises an elongated shaft, resembling the shafts of the whip-like flagella, complete with two canals, and also a broad, membranous base, resembling the bowl-shaped flagella. We found similar links to connect the flagella of all solifuge species. By clearly defining the components that form a flagellum and meticulously examining it on many species, we hypothesized that the flagella are homologous: they share a single origin on the common ancestor of all solifuges.

RUDO LOTTER

An undescribed diurnal male solifuge from the family Solpugidae carries a female of the same species in his jaws as part of the mating ritual before sperm transfer. The female shows distinct signs of temporary paralysis.

The new insights we have gained about solifuges are only a sampling of the sorts of questions it is now possible to explore. Much remains unknown about these arachnids' ecology. Armed with our atlas of terms to describe the various jaw structures and classify species, researchers can more systematically study how each body part functions to fill different needs. For instance, we now know which structures constitute flagella—but what do they do? It is clear that they contribute to reproduction, but how, exactly? Some reports suggest that they may play a role in copulation, such as sperm retention and transfer, or species-specific mate recognition. The structural differences of flagella across families, or even species, likely relate to functional differences. In the family Ammotrechidae, the male has been observed to place sperm in its bowl-shaped flagellum, which is then used to transfer the sperm to the female. In the family Solpugidae, the jaws themselves, not the flagellum, have been observed to transfer sperm to the female. However, in this family the male's long, whip-like flagellum is inserted deeply into the female's reproductive tract post-sperm transfer. It may deposit the contents from one of the flagellar canals, perhaps to facilitate fertilization in some way. The Eremobatidae family takes yet another approach: they transfer sperm directly, and the jaws—which still participate in other aspects of mating—are not involved in sperm transfer. It is probably no coincidence that the flagellum in this family, when present, is less elaborate than in other families, instead forming part of a cluster of modified setae. These bristles may detect whether the female is ready for sperm transfer before insemination, or whether sperm was actually transferred to the female post-insemination. More measurements of flagella and the reproductive tracts of different species, as well as observations of mating and other behavior, are needed to determine whether and how the flagella facilitate mating, or perhaps serve other functions.

In addition to defining terms, our initial goal, we were also able to analyze the features of the chelicera, and break down features of sexual dimorphism. Most features associated with feeding and defense are situated on the inside surfaces of the jaws, which show the least differences between species, but also between sexes. Parts of the jaws that seem more closely associated with reproduction are the outer sides of the jaws, which in males nearly always are clothed with a diversity of hairs and setae of various levels of robustness and shape, and the teeth and upper finger of the jaw, which differ in shape in males of different species and on which the flagellum is also situated.

Although at the end of the study, we were left with even more unanswered questions. We hope that our atlas and our findings will form a base for other studies, and that they will stimulate research into the mysteries of these animals, which can now be communicated with a unified terminology.

Tharina Bird is senior curator of invertebrates at the National Museum of Namibia. She recently completed her Ph.D. at Colorado State University in the United States.

Album cover: Lepidoptera: Larva, Food-Plant, Pupa, &c.

On the following pages the reader is treated to very rare views: illustrations by Titian Ramsay Peale II to accompany his unpublished manuscript The Butterflies of North America, Diurnal Lepidoptera: Whence They Come, Where They Go, and What They Do. *Both were given to the American Museum of Natural History by a Peale family descendant nearly one hundred years ago.*—Tom Baione

A Life of Artful Science

By Kenneth Haltman

The artist-scientist who devoted his life to producing *The Butterflies of North America*, Titian Ramsay Peale II, was an avid hunter, field naturalist, wilderness explorer, museum impresario, and early amateur photographer required by circumstance to work for decades in the patent office, predeceased by a first wife and all his children. He was a melancholy optimist buoyed by his eight-decade-long immersion in the study of Lepidoptera, whose metamorphoses he saw as a reminder of the possibilities of resurrection and renewal.

Peale's career spanned two worlds. He was born in Philadelphia in the last weeks of the eighteenth century, into a distinguished family for which artistic representation in various genres—including specimen portraiture and taxidermy, combined with the pursuit of scientific understanding—was a way of life. He died just blocks away at the height of the Gilded Age eighty-five years later in near poverty, his life's work unpublished.

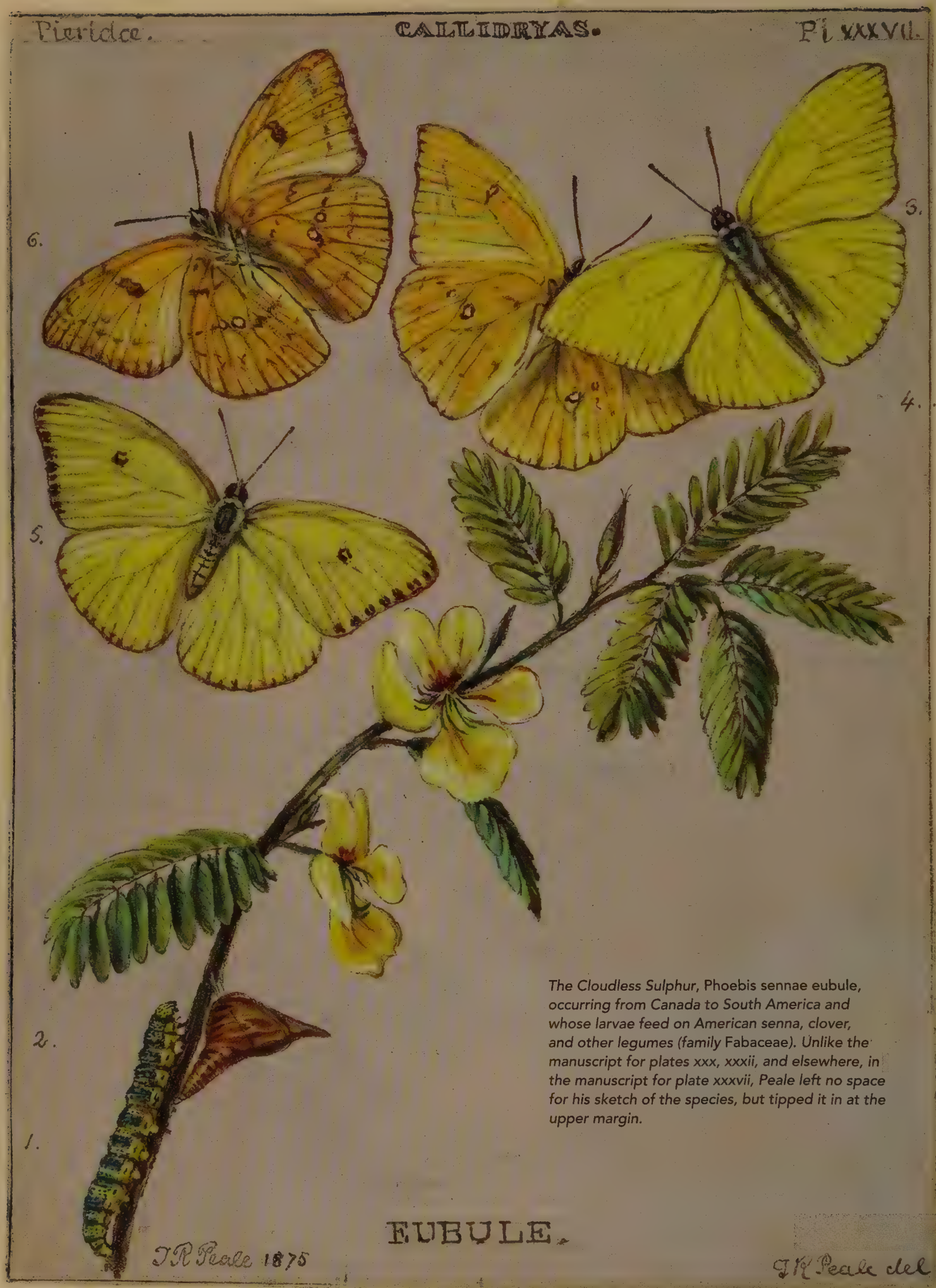
Caterpillar of the Buck Moth, Hemileuca maia *(family* Saturniidae*), on its oak host (*Quercus *species, family* Fagaceae*).*

Peale's father, Charles Willson Peale, natural historian and painter, was founder of the Philadelphia Museum (known to all as Peale's Museum)—the new nation's first collections of science and art open to the public. Charles named his son, rather auspiciously born in Philosophical Hall, where the museum was then located, on October 10, 1799, after an older brother who had recently died. That earlier Titian had been a lepidopterist of great promise whose unpublished manuscript *Drawings of American Insects: Shewing Them in Their Several States* (1796) held pride of place in the family library. In midlife, Peale would still brag to butterfly correspondents about his namesake's accomplishments.

By 1817, the teenage Peale had filled a Lepidoptera sketchbook of his own, which he titled *Sea[son]s of Appearance*, gently suggesting his allegiance to a shared familial, decidedly Romantic worldview, attuned not simply to the beauty of a butterfly's wings but to the equally beautiful rhythm of the changes that it underwent. Though Peale learned to compose detailed descriptions of each butterfly he sketched and later painted, he considered his artistic renderings vital to the process of recording and communicating scientific insight not just accurately but *effectively*. The purpose of his work was always also—if not principally—aesthetic and spiritual uplift, his images an experience of glorious, spiritual rebirth.

In 1816, Peale was just sixteen at the time of his first professional commission: to prepare six colored plates for

The Great Southern Sulphur, Ascia monuste, *showing the male, the female (seen above and below), a mature caterpillar and chrysalis on its spider flower host plant,* Cleome *species. (It also feeds on various* brassicas *and* nasturtium.*) The butterfly occurs from the southern United States to Argentina. In the manuscript page above right, Peale cut out his sketch of this species and pasted it on the page, writing his description around it.*



The Cloudless Sulphur, Phoebis sennae eubule, *occurring from Canada to South America and whose larvae feed on American senna, clover, and other legumes (family* Fabaceae*). Unlike the manuscript for plates xxx, xxxii, and elsewhere, in the manuscript for plate xxxvii, Peale left no space for his sketch of the species, but tipped it in at the upper margin.*

Figure 1. Caterpillar. 2 Chrysalis. 3-4 Male. 5-6 Female.
Food plant Cassia Chamæcristā.

a prospectus intended to attract subscribers to Thomas Say's projected publication, *American Entomology*. Those illustrations led to his election the following year to full membership in Philadelphia's newly founded Academy of Natural Sciences, whose Lepidoptera he would one day curate. That summer, Say invited him to accompany an exploratory expedition into the wilds of the American Southeast. Peale acquitted himself well enough as assistant naturalist, hunting and collecting specimens, to be hired to accompany the Stephen Harriman Long expedition to the Rocky Mountains (1819–20) in the same capacity. Over the course of the journey, the first federally sponsored scientific survey to explore the American West since the return of Lewis and Clark, working again with Say, he sketched and preserved hundreds of previously unrecorded botanical, zoological, ornithological, and entomological specimens. By prior arrangement, these eventually made their way into the family museum for preservation and display.

Over the next few years, Peale exhibited a few expedition watercolors and contributed drawings and paintings for thirty-two of the forty-two plates in Say's *American Entomology* (1824–28) and for ten plates in Charles Lucien Bonaparte's *American Ornithology* (1825–33). He married, began a family, and assumed direction of the museum with his brother Franklin after the death of their father in 1827. In 1833, he took over management of the museum, which was struggling to compete with more popular entertainments.

By 1836, he was tempted by the opportunity to accompany the United States South Seas Surveying and Exploring Expedition, and he was eventually placed under the command of Charles Wilkes as a member of the Scientific Corps. He may have hoped to renew public interest in the museum's collections through the addition of new specimens. The expedition lasted almost four years, from August 1838 to June 1842, and Peale collected and identified as many as four hundred new species of Lepidoptera in the Pacific Islands. Valuing the specimens obtained "too highly to trust them from my own care," as he later lamented, "these were not sent home with the other collections, but were unfortunately lost by the wreck of our ship," *The Peacock*, which foundered off the coast of Oregon in July 1841. Peale lost his private library and many of his notes as well, and his later preference to include insects in his published report on the expedition's zoological findings was overruled.

Upon Peale's return to Philadelphia, he learned that, in his absence, his extensive Lepidoptera collections, which had been transferred to the Academy, had been destroyed while in storage during a reinstallation. These professional setbacks were compounded by the final loss of the family museum and, more heartbreaking, by the one-upon-another deaths of his wife, a son, and a daughter. All this drove Peale deeper into butterflies. To make ends meet, in 1848 he took a job as assistant examiner with the United States Patent Office in Washington, in the division of Fine Arts and Photography. Two years later he remarried and bought a house that he soon filled with new photographic and vintage painting equipment, as well as guns, breeding cages, kill chambers, nets, and "rows upon rows of neatly arranged specimens of butterflies." He eventually rose to the rank of principal examiner at the patent office before his retirement in 1873 after twenty-five years.

To economize, and to gain access to library resources, he moved his household back to Philadelphia, living for a

Detail from caterpillar album, page 187, of what appears to be the Zebra Caterpillar Moth, Melanchra picta *(family* Noctuidae*).*

Life cycle of the Regal or Royal Walnut Moth, Citheronia regalis *(family* Saturniidae*), the caterpillar of which is called the Hickory Horned Devil, so named for the spines on the caterpillar and its predilection for hickory trees (*Carya *species, family* Juglandaceae*).*

time with a grandson who had previously lived with him in Washington, subsisting on his wife's income from a small inheritance. The Academy of Natural Sciences agreed once again to house Peale's collections and to provide him a room in which to work, with the purpose of compiling, completing, and then publishing a lifetime of images and descriptions that he now first referred to in correspondence

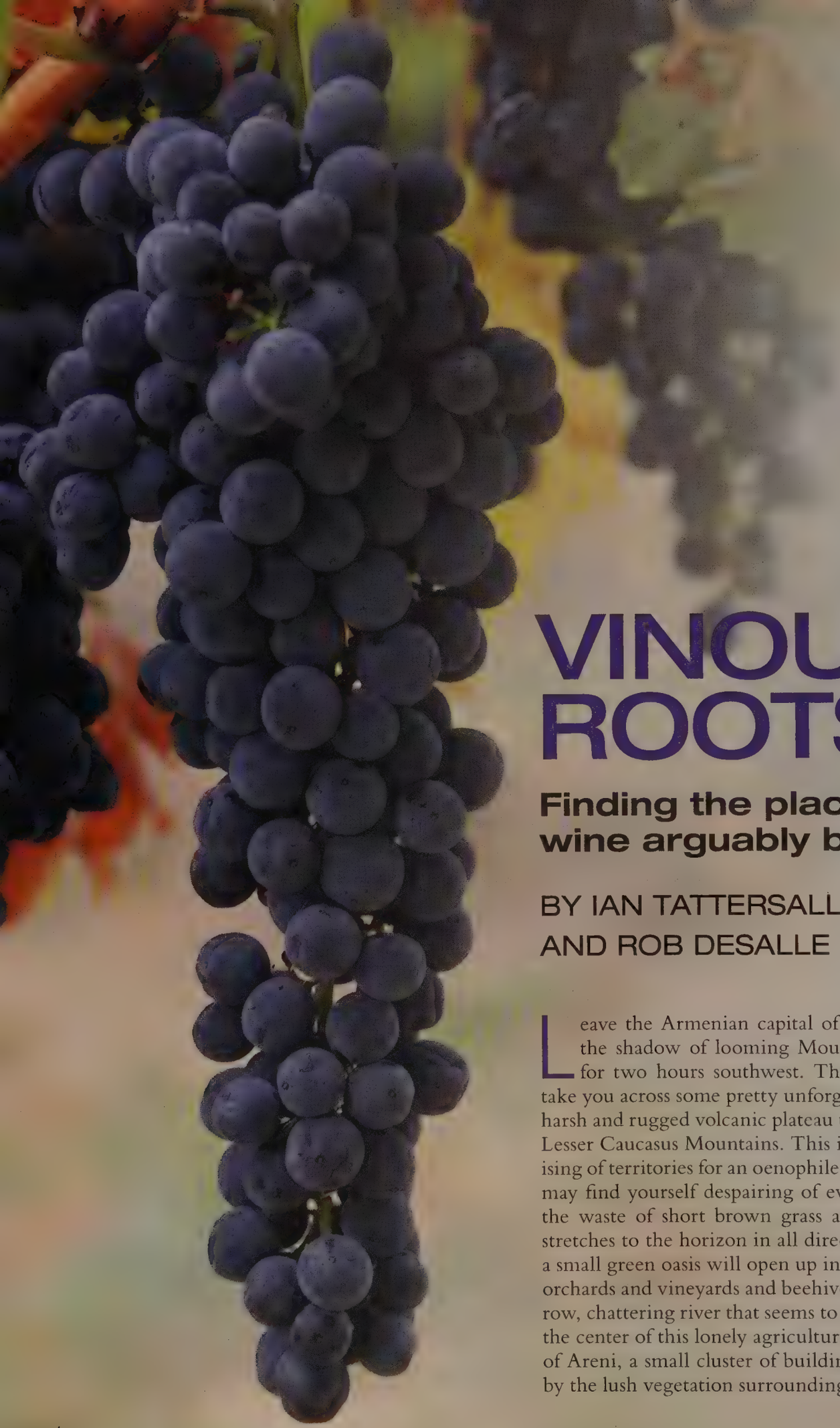
The Mourning Cloak, Nymphalis antiopa, *showing upper and under surfaces of the adult, upper and side views of the mature caterpillar, and a chrysalis. The Mourning Cloak is one of the first butterflies to appear in the spring throughout its range in North America, well into Canada and Alaska. Its caterpillars feed on willows, beeches, and other trees. As seen on the manuscript for this plate (above), Peale used neatly lettered, handmade labels to gather loose sheets of his manuscript. This is also one of several plate numbers that changed as Peale assembled his manuscript.*

as his *Butterflies of North America*. At once a synthesis of current knowledge and a retrospective of his own career, the project entailed cutting and pasting notes and images from more than fifty years of research.

Titian Peale died on March 13, 1885, after just a single day of illness, his manuscript, long labored over, though substantial in both breadth and scope, left unfinished, as quite a number of the plates Peale listed in his table of contents are either missing or were never completed. The science in Peale's images was designed for a general audience of enlightened thinkers with an interest in natural history, but the pictorial means that he deployed in communicating scientific insight with emotional and even spiritual resonance—his art—offered its invitation to any viewer.

Images and text from The Butterflies of North America: Titian Peale's Lost Manuscript, *Copyright 2015 American Museum of Natural History.*

Kenneth Haltman *(pictured) is the author of* Looking Close and Seeing Far: Samuel Seymour, Titian Ramsay Peale, and the Art of the Long Expedition, 1818–1823 *(Penn State University, 2008) and numerous other contributions to nineteenth-century American art history and material culture.* **Tom Baione** *is the Harold Boeschenstein Director of the American Museum of Natural History's Research Library.*



VINOUS ROOTS

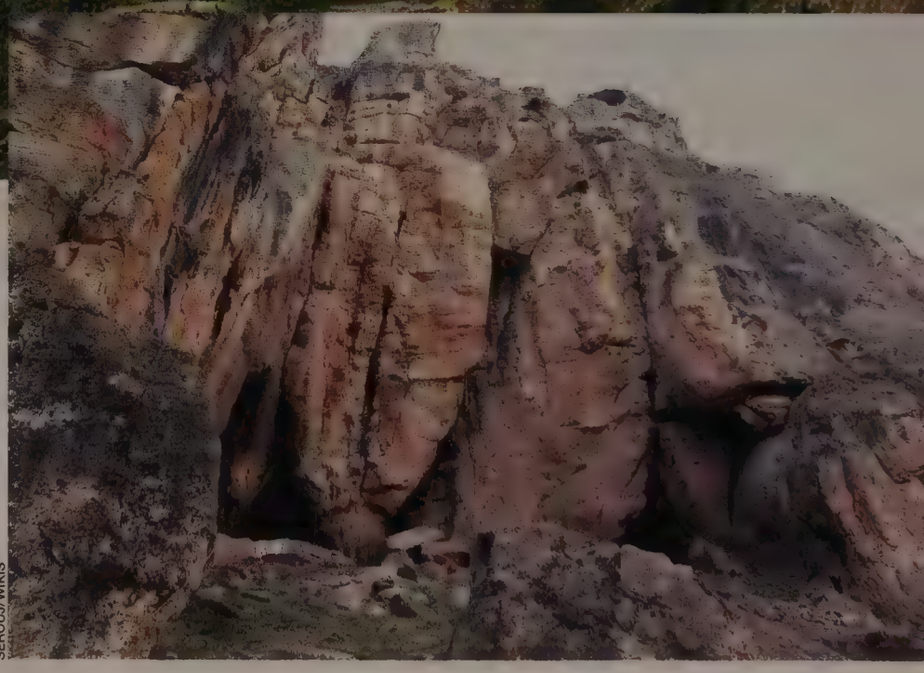
Finding the place where wine arguably began

BY IAN TATTERSALL AND ROB DESALLE

Leave the Armenian capital of Yerevan behind you in the shadow of looming Mount Ararat and drive fast for two hours southwest. The meandering road will take you across some pretty unforgiving terrain, part of the harsh and rugged volcanic plateau that lies at the foot of the Lesser Caucasus Mountains. This is hardly the most promising of territories for an oenophile, and before too long you may find yourself despairing of ever spotting a vine amid the waste of short brown grass and eroded hillsides that stretches to the horizon in all directions. But after a while, a small green oasis will open up in front of you: a cluster of orchards and vineyards and beehives, all given life by a narrow, chattering river that seems to spring from nowhere. In the center of this lonely agricultural outpost lies the village of Areni, a small cluster of buildings that is mostly hidden by the lush vegetation surrounding it. Although the village

5. Astvatsatsin (Holy Mother of God) church in Areni, Armenia, built in 1321

VIGEN HAKHVERDYAN



SEROUJ/WIKIS

Entrance to the Areni-1 cave complex in the village of Areni, Armenia, where the oldest known winery was discovered in 2007 by a team of Armenian and Irish archaeologists.

itself is as obscure as it is tiny, its name is not. You'll see that name on bottles of wine sold all over Armenia, not because Areni itself is nowadays a major wine producer but because centuries ago this little village gave its name to what some consider Armenia's finest wine grape.

But the people of Areni village know their wine, and they know their grape, and they probably correctly doubt that it can be grown to the same advantage anywhere else. After all, they will tell you, they have been growing these vines for centuries—for so long, indeed, that the memory of winemaking in these parts fades back into the mists of time.

The earliest cuneiform inscriptions referring to wine production in Greater Armenia date to the days of Urartu, a proto-Armenian kingdom centered in eastern Anatolia that flourished in the seventh and eighth centuries BC. Urartu was a major exporter of wine to neighboring Assyria, and most Urartian cities had important wine-storage facilities, some holding many thousands of liters, which testify to the beverage's economic importance. The first literary records of wine in the region come from the beginning of the fourth century B.C.E., when the soldier Xenophon, in his epic work *Anabasis*, described the retreat of a Greek mercenary army from Babylonia. Xenophon records that, as they fought their way across southern Armenia on their way to the Black Sea, the Hellenic forces "took up their quarters . . . in numerous beautiful buildings, with an ample store of provisions, for there was wine so plentiful that they had it in cemented cisterns." As ancient as Xenophon's account and the wine jars of Urartu may be, though, at Areni the story of wine began considerably earlier. For in a cave just outside the village, archaeologists have found traces of winemaking that probably date from a full six thousand years ago.

Past the bucolic Areni settlement, the scenery changes dramatically. As you leave the fertile valley behind,

Village of Areni

YAVUZ ÇOLAŞAN

you'll enter a narrow chasm carved by the river Arpa through a massive outcropping of limestone. And low on the sheer cliff to your right, just before the river is joined by a tributary running down an equally precipitous gorge, there opens the entrance to the cave that is now famous to archaeologists as Areni-1. First mapped in the 1960s by Soviet Cold War planners improbably on the lookout for places to shelter the sparse local population from nuclear attack, Areni-1 has since proven a bonanza for prehistorians, its extraordinary archaeological richness stemming from the many advantages it has offered people throughout history. Not only is the cave roomy and strategically located above the valley, but its arching portal made it a comfortable place for early humans seeking shelter from the elements. What's more, in later times the cave's interior provided ideal conditions for the preservation both of the dead and of the artifacts they used in life.

You can park your car in the shade of a sprawling grape arbor beside the bickering Arpa and scramble up a steep talus slope toward the cave entrance: a high, wide gash across the side of the cliff. As the narrow path flattens out onto the platform of sediment at the cave's mouth, you'll glimpse a partially excavated area in which archaeologists have already found hints of almost unimaginably long-term use of the cave by humans. At the bottom of the pile of occupation deposits, test pits have produced crude stone tools indicating that Ice Age hunter-gatherers were camping at Areni some hundreds of thousands of years ago, long before our species *Homo sapiens* came into existence. Doubtless these early humans were exploiting the rich bounty of a local environment that would have included fish teeming in the river as well as herds of migrating mammals that converged down the neighboring valleys. It is not hard to imagine those early human relatives perched outside the cave, scanning the river valley for approaching prey.

For now, though, the imagination must serve. Sadly for those interested in Ice Age lifeways, it will be a good while before we are able to say much more about the earliest inhabitants of Areni-1—though for the best of reasons. Because this place was always attractive to humans, the oldest layers at Areni are covered over by the remains of more recent occupations that will have to be painstakingly documented and removed before the Ice Age layers are reached.

Still, the archaeologists are in no hurry, for in the more recent layers they have been finding an unparalleled record of life in the crucial interval, some six thousand years ago, between the New Stone Age and the Bronze

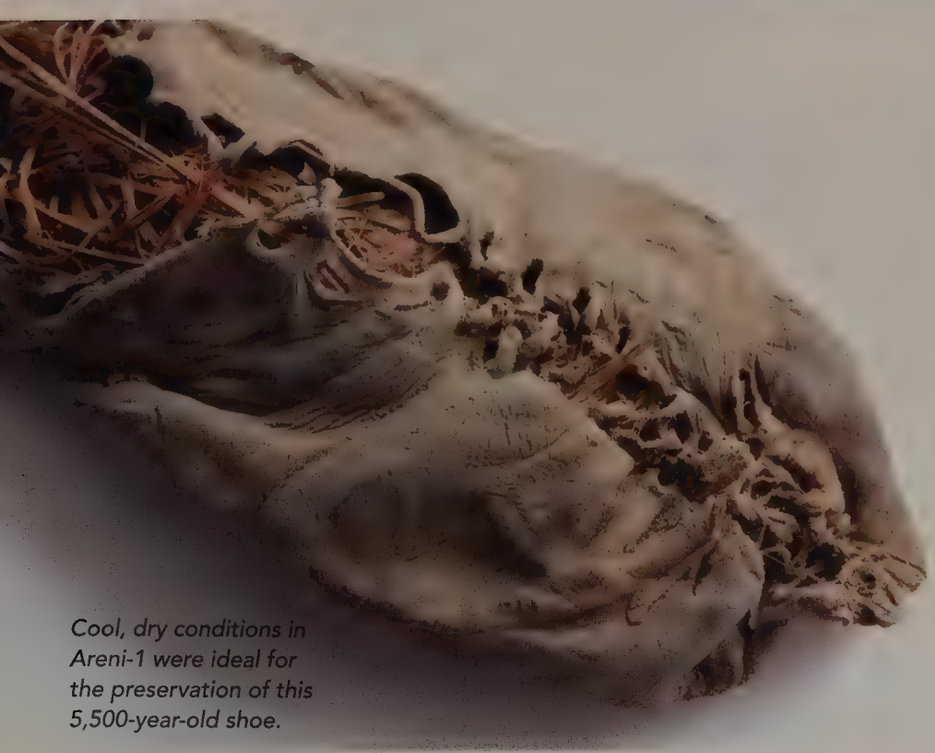
Age. This was a time when complex settled lifeways were just becoming established in the Near East, and when Areni-1's Chalcolithic (Copper Age) inhabitants were, among other things, burying their dead in the cave's gloomy interior.

As you leave the light and airy platform at the front of the cave and proceed deeper into the rock, the natural illumination is gradually replaced by a string of feeble lightbulbs that reveal a tall, winding passageway bounded by a deep pit on the left. A sharp right turn, through what is in effect a natural airlock, brings you to a wider section of the cave, in which shallow excavations into the floor have revealed evidence of several extensive Chalcolithic occupations.

What makes the findings at Areni-1 special is that the cool, dry conditions beyond the airlock proved ideal for the preservation of light organic materials of the kind that usually rot away rapidly and disappear. Rarities of preservation include pieces of rope, textiles, and wooden implements—even a complete shoe, made from a single piece of leather. This remarkable artifact caused quite a stir when it was first reported, not only because of its excellent preservation but also because of its age: in the entire archaeological record of the Old World, only the damaged shoes worn by Ötzi the Ice Man, the natural mummy of a Chalcolithic hunter discovered in 1991 after an Alpine glacier melted, come anywhere close to its antiquity. And Ötzi's grass-stuffed shoes are several hundred years younger than the Areni moccasin.

ARMENIAN INSTITUTE OF ARCHAEOLOGY AND ETHNOGRAPHY

Some of the many pottery jars found in the Areni-1 cave. Their use for wine storage was determined by their resemblance to those found in wineries known from later times.



Cool, dry conditions in Areni-1 were ideal for the preservation of this 5,500-year-old shoe.

Equally remarkable at Areni-1, though, is the extent of the evidence about their everyday existence that the ancient people left behind. Within the shelter they built dwellings with durable walls and smooth, plastered floors; they cooked food over hearths; they made tools of obsidian and chert; they ground grains on flat stones—and they made wine. Indeed, the Chalcolithic people of Areni-1 have bequeathed to us the remains of the world's earliest winery: the first tangible physical evidence we have, from anywhere, of a society's devotion to the fermented juice of the grape.

In 2007, archaeologists were carefully removing the superficial occupation debris that had accumulated in the cave when they found their way down to a layer that revealed a shallow, flat-bottomed basin with raised edges, scraped into

The annual Areni Wine Festival celebrates the region's traditions in food, dress, dance, and wine making.

the hard-packed clay of the ancient cave floor. The bottom of this basin sloped slightly, toward the mouth of a large (60-liter) pottery jar that was sunk into the cave floor beside it. The scientists at once recognized the flat platform as a surface on which ancient grapes had been trodden (presumably by unshod feet). The juice had drained naturally into the jar, which had clearly served as a fermentation vat. The cool, dry conditions of the cave would have provided a perfect environment for the fermentation process, as well as for the wine's later storage in the many other pottery jars lying in the immediate vicinity. The purpose of this unusual archaeological feature was apparent from the start, not only because of its resemblance to wineries known from later times but because the treading area was littered with grape seeds and stems from a strain of today's favored winemaking vine species, *Vitis vinifera*.

This staggeringly old winery was an exciting find, especially given the sophisticated arrangement of the pressing floor and the large size of the fermentation vat. Usually scientists who try to find traces of the very early production and consumption of wine have to make do with more indirect evidence, most notably the chemical residues that form on the insides of containers used to store the wine. The study of such residues has an intriguing history in archaeology (colleagues recently found traces of marijuana inside Elizabethan clay pipe stems dug up in William Shakespeare's garden in Stratford-upon-Avon), but the evidence is not always easy to interpret. A handful of potsherds found on the grape-pressing floor at Areni-1, for example, radiocarbon-dated to between 6,100 and 6,000 years ago, proved to carry residues of malvidin, a major pigment in grape skins that is responsible for the color of red wine. A wonderful discovery, but a bit equivocal nonetheless: malvidin is also present in fruits other than grapes, such as pomegranates, which still grow around Areni today.

Because the source of the malvidin might not have been grapes, Patrick McGovern, the leading expert on analyses of this kind, noted that he would have been more comfortable if traces of tartaric acid had also been found on the pottery fragments. For unlike malvidin, in the Near Eastern environment tartaric acid is a compound pretty much confined to grapes. Still, given all the supporting evidence that the structure at Areni-1 was a winery, it seems reasonable to conclude that the malvidin came from wine.

Excerpted from *A Natural History of Wine* by Ian Tattersall and Rob DeSalle, published by Yale University Press. Copyright ©2015 by Ian Tattersall and Rob DeSalle. Excerpted by permission of Yale University Press. All rights reserved.

Ian Tattersall is curator emeritus in the Division of Anthropology, American Museum of Natural History (AMNH), New York City. His recent research interests, how and when *Homo sapiens* became an extraordinary cognitive entity, led to publication in 2012 of *Masters of the Planet: The Search for Our Human Origins*. **Rob DeSalle** is curator of entomology in the Sackler Institute for Comparative Genomics, AMNH. Tattersall and DeSalle have collaborated on previous books, the most recent being *The Brain: Big Bangs, Behaviors, and Beliefs* (Yale University Press, 2012).

Fuel for Thought

Ten times a year, *Natural History* delivers feature articles that are well-researched, carefully written and edited, and beautifully illustrated. Columnists are thoughtful, informative, and thought-provoking. The magazine operates on a lean admixture of material provided by scientists, columnists, and book publishers *at no charge*, fueled primarily by reader support. But the magazine can't run on empty. Printing, paper, postage, and people need to be paid, and subscription revenue alone is not enough. This is the time of year when Friends of Natural History Foundation asks for your support.

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Image used to illustrate Natural History*'s three-part series [3, 4, 5/15] from* "Junk DNA: A Journey Through the Dark Matter of the Genome" *by Nessa Carey (Columbia University Press, 2015).* "Pictures of Junk: Narcissus, after Caravaggio," *by Vik Muniz, 2005*

THIS LAND BY ROBERT H. MOHLENBROCK

Highs and Lows

One of Illinois's remaining natural areas has its ups and downs.

Overlooking Kidd Lake Marsh State Natural Area

Hill prairies are patches of prairie vegetation located at or near the top of hills or rocky cliffs, usually surrounded by woods. Most hill prairies face to the west. They occur in much of the Midwest, but exhibit some variation. The hill prairies along the western border of Iowa are on top of deposits of windblown soil called loess, with very little exposed rock surface. Since they are near the Great Plains, several western prairie species grow on them. On the other hand, the hill prairies that border the Mississippi and Illinois rivers in Illinois are usually perched on rocky cliffs and lack many of the prairie species of the Great Plains.

Hill prairies occur all along the Mississippi River from southern Wisconsin and Minnesota to southern Illinois, and along the Illinois River from north of Peoria to the junction of the Illinois River with the Mississippi.

Fults Hill Prairie Nature Preserve in Monroe County, Illinois, has a great diversity of prairie plants and is adjacent to limestone ledges and a cliff face that harbors plants rarely encountered in this part of the country. In addition, at the base of the Fults bluffs and extending into the Mississippi River floodplain is the pristine 465-acre Kidd Lake State Natural Area.

Hill prairies often occur on such steep slopes that it is not practical to farm the areas or

HABITATS

Hill Prairie Other prairie species in the Fults Hill Prairie include round-headed bush clover, horsetail milkweed, prairie tickseed, tall tickseed, lead plant, tall boneset, false dragonhead, showy goldenrod, and hoary vervain.

Ravine Woods Trees that are common in the ravine woods are green ash, northern red oak, sugar maple, shagbark hickory, bitternut hickory, American elm, hop hornbeam, hackberry, and musclewood. Spicebush is a common shrub.

Dry Woods This habitat is dominated by black oak, white oak, post oak, chinquapin oak, mockernut hickory, and white ash. Smaller trees include sassafras and flowering dogwood.

Kidd Marsh Other plants in Kidd Marsh are swamp rose mallow, fringed yellow loosestrife, soft rush, and several species of the sedge genus *Carex*.

to use them for livestock grazing. Nonetheless, because of the invasion of woody plants into the prairies, most of them have become reduced in size throughout the years. Fults Hill Prairie has shrunk by about 30 percent since 1955. Biologists conduct controlled burns every few years in an effort to preserve the prairie from the invasion of woody plants.

Although prairie grasses are dominant at Fults—with the major ones being big bluestem, little bluestem, Indian grass, switchgrass, nodding wild rye, junegrass, and side-oats gramma—an incredible number of prairie wildflowers are also abundant. July and August are the best times to see most of these in bloom. At Fults, the most common are purple prairie clover, white prairie clover, pale coneflower, flowering spurge, false boneset, green milkweed, scurf pea, narrow-leaved mountain mint, rosinweed, sky blue aster, silky aster, stiff goldenrod, rattlesnake-master, prairie blazingstar, and butterfly weed.

In the spring, hairy wild petunia, Ohio spiderwort, wild bergamot, pale beardtongue, hoary puccoon, and thimbleweed are showy. Native shrubs, some of which try to invade the prairie, are New Jersey tea and Carolina rose. A few Illinois rarities in the Fults Hill Prairie are crested coralroot orchid, scented ladies'-tresses, and Missouri coneflower.

The limestone ledges at the edge of the hill prairie are home to several western species that are very rare in Illinois. Their seeds were probably blown there by strong westerly winds. Among the rarest are slender heliotrope, few-seeded stickleaf, dwarf bedstraw, and Texas aster, the last known only from the ledges at Fults.

To get to the prairie and limestone ledges requires hiking a rather steep trail that goes through a ravine woods and up through a dry woods before reaching the lower edge of the prairie.

The ravine woods contains several spring wildflowers, beginning in late March with bloodroot, quickly followed by spring beauty, toothwort, white trout lily, wild geranium, bellwort, Dutchman's-breeches, woodland phlox, Virginia bluebells, jack-in-the-pulpit, recurved trillium, woolly blue violet, and smooth blue violet.

As one approaches the hill prairie, the ravine woods merges into a drier woods where the species composition is much different. In addition to the trees found in the dry woods (see below), two trees rare for southern Illinois are found: blue ash and woolly buckthorn.

Access to the Fults Hill Prairie Nature Preserve is from a small parking lot on the north side of Bluff Road which passes along the base of the imposing limestone cliffs. The parking area is about seven miles south of Valmeyer, IL and just past the tiny community of Fults. The St. Louis metropolitan area is approximately a thirty-minute drive. For more complete directions, visit www.greatriverroad.com/stegen/monroe/fults.htm#sthash.GPmReedw.dpuf.

ALAN CRESSLER

Fringed yellow loosestrife, Lysimachia ciliata

VISITOR INFORMATION:
Randolph County State Conservation Area
4301 S. Lake Drive
Chester, IL 62233
1-618-826-2706
http://dnr.state.il.us/Lands/landmgt/parks/R4/fhp.htm

On the other side of the road from the parking area is Kidd Lake Marsh Natural Area, a vast Mississippi River floodplain with extensive marshland. Many species of marsh plants are present. In areas of standing water are American lotus, spatterdock, fragrant water lily, large arrowhead, arrow arum, water smartweed, river bulrush, swamp dock, and broad-leaf cattail. In areas of shallow water which often dry out during the summer are lizard's-tail, false aster, marsh purslane, valley redstem, low rotala, dwarf St. John's wort, American water horehound, clammy hedge hyssop, ditch stonecrop, and several kinds of smartweeds. Prairie cordgrass is common in much of the area.

The diversity and number of amphibians in Kidd Marsh are remarkable. Among these are northern spring peeper, southern leopard frog, American toad, and bullfrog. One early spring day when I was driving along Bluff Road near Kidd Marsh, I had to stop and let hundreds of these creatures cross the road.

ROBERT H. MOHLENBROCK is a distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.

Around the Country

Out-of-World Experience

If you want to feel the disorientation of an environment that has no sense of up or down, visit the California Science Center's new "Journey to Space: The Exhibition," opening on October 29. Examine the challenges and innovative solutions required for human space exploration, including the very real dangers astronauts face during their missions high above the Earth. Get a feeling for what space is like, how we are learning to live and work in space, and how we are preparing for bolder and more distant missions. Through hands-on displays and immersive experiences, explore the science and technology developed by scientists to protect astronauts from radiation, meteoroids, temperature extremes, and the vacuum of space. Hear the stories of astronauts and rocket scientists, take a turn managing the energy of a simulated orbiting space station, operate a robotic arm, and find out how astronauts eat, sleep, and even go to the bathroom in space.

Exhibition highlights include a real glove used by Neil Armstrong, and a rotating chamber inspired by the International Space Station's Destiny Module that you can enter if you want to feel a bit topsy-turvy.

"Journey to Space" features a full-scale replica of the Destiny Lab, the primary research facility for U.S. payloads on the International Space Station. With its rotating mechanism, guests stepping into the Destiny Lab will have their sense of orientation challenged as they get a virtual tour from astronauts who have worked there.

CALIFORNIA SCIENCE CENTER

Exposition Park
700 Exposition Boulevard, Los Angeles, CA
323-SCIENCE (323-724-3623) • www.californiasciencecenter.org
Through May 8, 2016

ARIZONA

Phoenix

ARIZONA SCIENCE CENTER

Ongoing: **"Get Charged Up."** Humans are naturally curious and the science of observation helps us understand the natural world around us—how things work and why.

600 East Washington Street
602-716-2000
www.azscience.org

CALIFORNIA

Los Angeles

NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

Through January 18, 2016: **"Mummies: New Secrets from the Tombs."** Get a rare, up-close look at a selection of more than 20 mummies originating from ancient Egypt and Peru—and from many historic ages—many of which have never been on public display. At interactive touch tables, visitors can "unwrap" layers of mummies to see the precious objects the bodies were buried with, as well as explore vivid details about the individual children, teens, and adults who lived out their lives in ancient times.

Exposition Park
900 Exposition Boulevard
213-763-DINO
www.nhm.org

San Diego

SAN DIEGO NATURAL HISTORY MUSEUM

Through January 3, 2016: **"Maya: Hidden Worlds Revealed."** This exhibition uses a combination of hundreds of authentic artifacts, immersive environments, multimedia components, and hands-on activities to explore the rise and eventual decline of this fascinating civilization. Visitors are given a glimpse at a cross-section of Maya life—from divine kings who ruled powerful cities to the artisans and laborers who formed the backbone of Maya society.

Balboa Park
1788 El Prado
619-232-3821
www.sdnhm.org

COLORADO

Denver

DENVER MUSEUM OF NATURE AND SCIENCE

Through January 31, 2016:

"The International Exhibition of Sherlock Holmes." Try out experiments featuring innovations in ballistics, forensics, and other techniques from the 1890s that are still relevant today.
2001 Colorado Boulevard
303-370-6000
www.dmns.org

CONNECTICUT

New Haven

PEABODY MUSEUM OF NATURAL HISTORY

Through January 3, 2016: **"Samurai and the Culture of Japan's Great Peace."** This exhibition brings to life the many-layered history of the samurai and those they ruled—a history full of drama and paradox. Visitors will encounter shimmering swords and intimidating armor, and discover that most were actually made at a time when war had passed from memory into myth. The exhibition features more than 150 spectacular artifacts from four Yale collections.
Yale University
170 Whitney Avenue
203-432-5050
www.peabody.yale.edu

DELAWARE

Wilmington

DELAWARE MUSEUM OF NATURAL HISTORY

Ongoing: **"Darwin and Evolution."** This permanent exhibition about Charles Darwin and evolution documents the scientist's life, experiences, and explanation for his groundbreaking theory.
4840 Kennett Pike
302-658-9111
www.delmnh.org

FLORIDA

Gainesville

FLORIDA MUSEUM OF NATURAL HISTORY

Now open: **"Depth of Field: Our World in Focus."** See magnified images of more than a dozen specimens and artifacts in the new West Gallery exhibition. These unique images are part of an ongoing project to digitally catalog the museum's collections, allowing people around the world to view the items online, and facilitating collaborations with other institutions.
University of Florida,
Cultural Plaza
SW 34th Street and Hull Road
352-846-2000
www.flmnh.ufl.edu

GEORGIA

Atlanta

FERNBANK MUSEUM OF NATURAL HISTORY

Through January 3, 2016: **"Searching for the Queen of Sheba."** This new special exhibition will bring together ancient artifacts from Yemen, contemporary Ethiopian artwork, archaeological reconstructions, and modern media to explore the mystery of this legendary Queen.
767 Clifton Road NE
404-929-6300
www.fernbankmuseum.org

HAWAII

Honolulu

BISHOP MUSEUM

Through February 28, 2016: **"Duke Paoa Kahanamoku."** This exhibition brings the many facets of Duke Kahanamoku to life by enlivening the J. M. Long Gallery with graphics, photographs, cultural artifacts, video clips, and interactive media displays.
1525 Bernice Street
808-847-3511
www.bishopmuseum.org

IDAHO

Idaho Falls

MUSEUM OF IDAHO

Through November 28: **"Real Pirates."** This exhibition tells the story of the *Whydah*, the first fully authenticated pirate shipwreck ever discovered and the only one in U.S. waters. The exhibit showcases more than 200 artifacts, which provide visitors with an unprecedented glimpse into 18th-century piracy.
200 North Eastern Avenue
208-522-1400
www.museumofidaho.org

ILLINOIS

Chicago

THE FIELD MUSEUM

Ongoing: **"The Ancient Americas."** Explore the Aztec empire and its island capital, Tenochtitlan, a city of more than 200,000 people and an extraordinary feat of engineering for any era.
1400 South Lake Shore Drive
312-922-9410
www.fieldmuseum.org

W. GUTH

This unusual samurai face guard and helmet, adorned with golden sea urchins, is now on view in the exhibition "Samurai and the Culture of Japan's Great Peace," at the Peabody Museum of Natural History in New Haven.

MEMBERSHIP HAS ITS REWARDS

Institutions marked with participate in the Passport program run by the Association of Science-Technology Centers (ASTC). If you're a member of a participating museum or science center, you may receive free admission at nearly 350 other museums and science centers around the world.

See www.astc.org/passport for more information.

MASSACHUSETTS
Cambridge
HARVARD MUSEUM OF NATURAL HISTORY
Now open: **"Islands: Evolving in Isolation."** This exhibition unravels the mysteries of island biodiversity and evolution. With examples from around the globe, it brings together an enormous array of plant and animal specimens, including lizards, giant pitcher plants, hissing cockroaches, Galápagos tortoises, New Guinea birds–of–paradise, Malagasy lemurs, a remarkable Komodo dragon from the Indonesian islands, and a rare fossil cast of *Homo floresiensis*, a relative of modern humans.
26 Oxford Street
617-495-3045
www.hmnh.harvard.edu

MINNESOTA
Minneapolis
BELL MUSEUM OF NATURAL HISTORY
Through January 3, 2016: **"Peregrine Falcon: From Endangered Species to Urban Bird."** This exhibition tells the incredible story of the citizens, scientists, and birds that brought these raptors back from the brink of extinction—in an unprecedented turn of events, peregrines were listed and then removed from the U.S. endangered species list within two decades. Learn how conservationists today are applying those same methods to other endangered species.
University of Minnesota
10 Church Street, SE
612-624-7083
www.bellmuseum.umn.edu

Visitors will delight in exploring the pathways and forests of "Hideaway Woods," the new outdoor learning environment at the Museum of Life and Science in Durham.

MISSOURI
Saint Louis
SAINT LOUIS SCIENCE CENTER
Ongoing: **"Energizer Machine."** Experience the wonder of simple machines working together in this amazing kinetic sculpture.
5050 Oakland Avenue
800-456-SLSC
www.slsc.org

NEW MEXICO
Albuquerque
NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE *Ongoing:* **"FossilWorks."** This exhibition features the process of extracting dinosaur fossils from the rock matrix that has encased them for millions of years. **FossilWorks** is a public display area in which volunteer preparators—who have completed a special training course—demonstrate the painstaking process of paleontological preparation.
1801 Mountain Road NW
505-841-2800
www.nmnaturalhistory.org

NEW YORK
New York
AMERICAN MUSEUM OF NATURAL HISTORY
Through January 3, 2016: **"Life at the Limits: Stories of Amazing Species."** Discover specialized adaptations that allow life to thrive even in the most unlikely places on Earth. Imagine holding your breath for an hour and a half. Enduring temperatures above 300° F and below -458° F. Or seeming to cheat death by repeatedly cloning yourself. This exhibition explores the diverse and sometimes jaw-dropping strategies animals and plants employ to find food, fend off predators, reproduce, and thrive in habitats that are inhospitable.
Central Park West at 79th Street
212-769-5100
www.amnh.org

Tupper Lake
THE WILD CENTER, NATURAL HISTORY MUSEUM OF THE ADIRONDACKS
Now open: **"Wild Walk."** A trail of bridges leads high above the Adirondack forest where visitors can walk over the tree tops and explore the stunning natural environment from a new perspective. The recently-opened Wild Walk includes a four-story twig tree house, swinging bridges, and a spider's web where guests can play, and observe the forest below. There's even an oversized bald eagle's nest at the highest point where visitors can perch and imagine life as one of the raptors.
45 Museum Drive
518-359-7800
www.wildcenter.org

NORTH CAROLINA
Durham
MUSEUM OF LIFE AND SCIENCE
Now open: **"Hideaway Woods."** This new nature playspace is a two-acre, forested learning environment featuring treehouses, a flowing streambed, and fanciful nature sculptures. Connected by rope bridges, the treehouse village encourages you to flex your body and imagination all while view-

ing the world around you from a new perspective (up to 20 feet off the ground).
433 West Murray Avenue
919-220-5429
www.ncmls.org

Raleigh

North Carolina Museum of Natural Sciences
Through March 27, 2016: **"Extreme Mammals."** This eye-opening exhibition explores the diversity of the biggest, smallest, and most amazing mammals that have ever roamed the Earth.
11 West Jones Street
919-707-9800
www.naturalsciences.org

OREGON

Eugene

Museum of Natural and Cultural History
Ongoing: **"Highlights of the Jensen Arctic Collection."** Journey into the unique cultures and ecosystems of the Arctic. The Jensen Collection represents one of the largest assemblages of Arctic material in the lower forty-eight states, and is a valuable record of life in a rapidly changing region.
1680 East 15th Avenue
541-346-3024
natural-history.uoregon.edu

PENNSYLVANIA

Philadelphia

The Academy of Natural Sciences of Drexel University
Through January 10, 2016: **"Reptiles: The Beautiful and the Deadly."** Get eyeball to eyeball with live deadly snakes, colorful lizards, bizarre turtles, and rugged crocodilians from around the world. Nestled in naturalistic habitats, these cold-blooded animals will help dispel common myths and foster a basic understanding of how reptiles fit into the animal kingdom and their native environments. Engaging, interactive components let visitors "milk" a viper, learn to speak croc in less than five minutes, and test their knowledge with Turtle Trivia and Lizard Wizard. Almost 20 species of live reptiles are on display.
1900 Benjamin Franklin Parkway
215-299-1000
www.ansp.org

TEXAS

Houston

Houston Museum of Natural Science
Through January 17, 2016: **"Spies, Traitors, Saboteurs: Fear and Freedom in America."** This exhibition reveals nine major events and periods in U.S. history when the nation was threatened by enemies within its borders, and examines how the government and the public responded.
5555 Hermann Park Drive
713-639-4629
www.hmns.org

UTAH

Salt Lake City

Natural History Museum of Utah
Through January 3, 2016: **"Birds of Paradise: Amazing Avian Evolution."** Fascinating stories of groundbreaking research and adventure paired with amazing footage and photography are the foundation of this highly interactive exhibition. "Birds of Paradise" captures these unique species with stunning imagery, compelling video, soundscapes, artifacts, and engaging educational activities for all ages.
301 Wakara Way
801-581-6927
nhmu.utah.edu

WASHINGTON

Seattle

Pacific Science Center
Through January 3, 2016: **"Grossology: The (Impolite) Science of the Human Body."** Explore the good, the bad, and the down-right ugly about how your body works. Discover the mysterious ways your body's biology does what it needs to do to keep you healthy.
200 Second Avenue North
206-443-2001
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This life-size recreation of the boy king driving a magnificent chariot is on display in the exhibition "Crossroads of Civilization," at the Milwaukee Public Museum. The forensic reconstruction of Tut's facial features are based on CT scans performed on his mummy.

SKYLOG BY JOE RAO

A Visual Aid to Andromeda

High overhead during the early evening hours is a star configuration that people unfamiliar with the sky often mistake for the Big Dipper. Big it is, but a dipper it is not. It does, however, point the way to the Great Andromeda Galaxy, the Milky Way's nearest neighbor and the farthest object in the sky that can be seen from Earth with unaided eyes. The bowl of this ersatz dipper is composed of the four stars of the Great Square of Pegasus, the Flying Horse. Pegasus actually supplies only three stars of the Great Square: Markab, Scheat, and Algenib. The fourth is Alpheratz, the alpha, or brightest, star of Andromeda. The handle is composed of four bright stars. Alpheratz, Mirach, and Almach are almost evenly spaced toward the northeast and are the brightest stars in Andromeda. The next bright star extending along the same line, Mirfak, is the alpha star of Perseus. If the night is crystal clear and you use this "dipper" as a guide, you will find your way to the Great Andromeda Galaxy.

In the year 964 AD, in his "Book of Fixed Stars," the Persian astronomer al-Sūfī (Abd al-Rahman al-Sufi) drew attention to a "little cloud" located among the stars of the constellation Andromeda, the Chained Princess. German astronomer Simon Marius (1573–1624) is usually credited with the first telescopic observation of this object around the year 1612. Even today, binoculars and telescopes reveal that "cloud" as little more than an elongated fuzzy patch, which gradually brightens in the center to a star-like nucleus. The light from this formation has been traveling some two-and-a-half million years to reach you, at the tremendous velocity of 671 million miles per hour. That "little cloud" is the total accumulation of light (based on observations from the Spitzer Space Telescope) from one trillion stars that form the Great Andromeda Galaxy.

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Joe Rao is a broadcast meteorologist and an associate and lecturer at the Hayden Planetarium in New York City (www.haydenplanetarium.org).

NOVEMBER NIGHTS OUT

3 Last Quarter Moon at 7:24 A.M. Venus is the dazzling "Morning Star," and remains gloriously high, rising more than three-and-a-half hours before sunup all month. Its altitude a half hour before sunrise declines only a little for mid-northern viewers from about 37° to 32°. This morning, take note of the much dimmer (by a full six magnitudes) yellow-orange Mars sitting just 0.7° to the upper left of Venus.

5–12 Taurid meteors are most active. Under clear, dark sky conditions, about a dozen or so per hour may be seen (city lights or even slight haze will substantially reduce that count). Although the constellation Taurus, from where these meteors appear to radiate (hence their name), rises around the time evening twilight ends, good counts should not be expected for several hours, until the radiant has moved well up in the eastern sky.

6 Jupiter rises around 1:50 A.M. The best time for viewing it is just before the break of dawn, when it will be shining brightly very high in the southeast. The giant glares at magnitude -1.9. It will be positioned 2.6° to the Moon's upper left. Binoculars or a small telescope will give fine views of Venus passing close to three fairly bright stars in Virgo during the first three weeks of this month. This morning at dawn, Venus is 0.2° north of Beta Virginis, magnitude +3.8.

7 Early this morning, just twenty-four hours after its rendezvous with Jupiter, a slightly thinner crescent Moon pays Venus and Mars a visit. Dazzling Venus will be sitting just 1.6° to the upper left of the Moon, while dim Mars can be found 2.2° above the Moon.

11 New Moon at 12:47 P.M. EST

13 Early this morning, Venus passes only 9 arcminutes (0.15°) north of Eta Virginis, magnitude +4.0. As seen from China, Venus and this star appear even closer, only 5 arcminutes apart.

17 Mercury passes through superior conjunction (beyond the Sun) and into the evening sky today, but this planet remains too close to the Sun to observe all of this month. Venus is 1.1° to the lower right of the close double star Gamma Virginis (Porrima) this morning.

18 The Leonid meteors reach their sharply peaked maximum this morning. The Moon will set at around 10:15 P.M., before the radiant rises. Observing conditions continue to improve throughout the night, until morning twilight begins to interfere around 5:00 A.M. Substantial numbers of shower members should not be expected until after 2:00 A.M., when the radiant has climbed at least 30° into the sky.

19 First Quarter Moon at 1:27 A.M. EST

25 Full Moon at 5:44 P.M. EST

26 If you live anywhere north of a line that runs roughly from Brookings, OR to Georgetown, SC on this Thanksgiving morning, you'll be able to see the almost-full Moon hide ("occult") the orange first-magnitude star Aldebaran, in Taurus, the Bull. See: http://asa.usno.navy.mil/static/files/2015/occns/occn.2015Nov26.Aldebaran.pdf. South of the line, the Moon narrowly misses covering the star. You definitely will need binoculars or a small telescope to watch this, as the overpowering glare of the Moon will make it impossible to see the disappearance (on the Moon's left edge) or reappearance (on the Moon's right edge) with the unaided eye.

29 About 4.2° to the lower right of Venus this morning is the bluish first-magnitude star Spica, the brightest star in the zodiacal constellation of Virgo, the Maiden.

30 Saturn slipped into the bright evening twilight at mid-month and disappeared in the glare of the Sun. Today it passes behind the Sun, lost from view until later in December.

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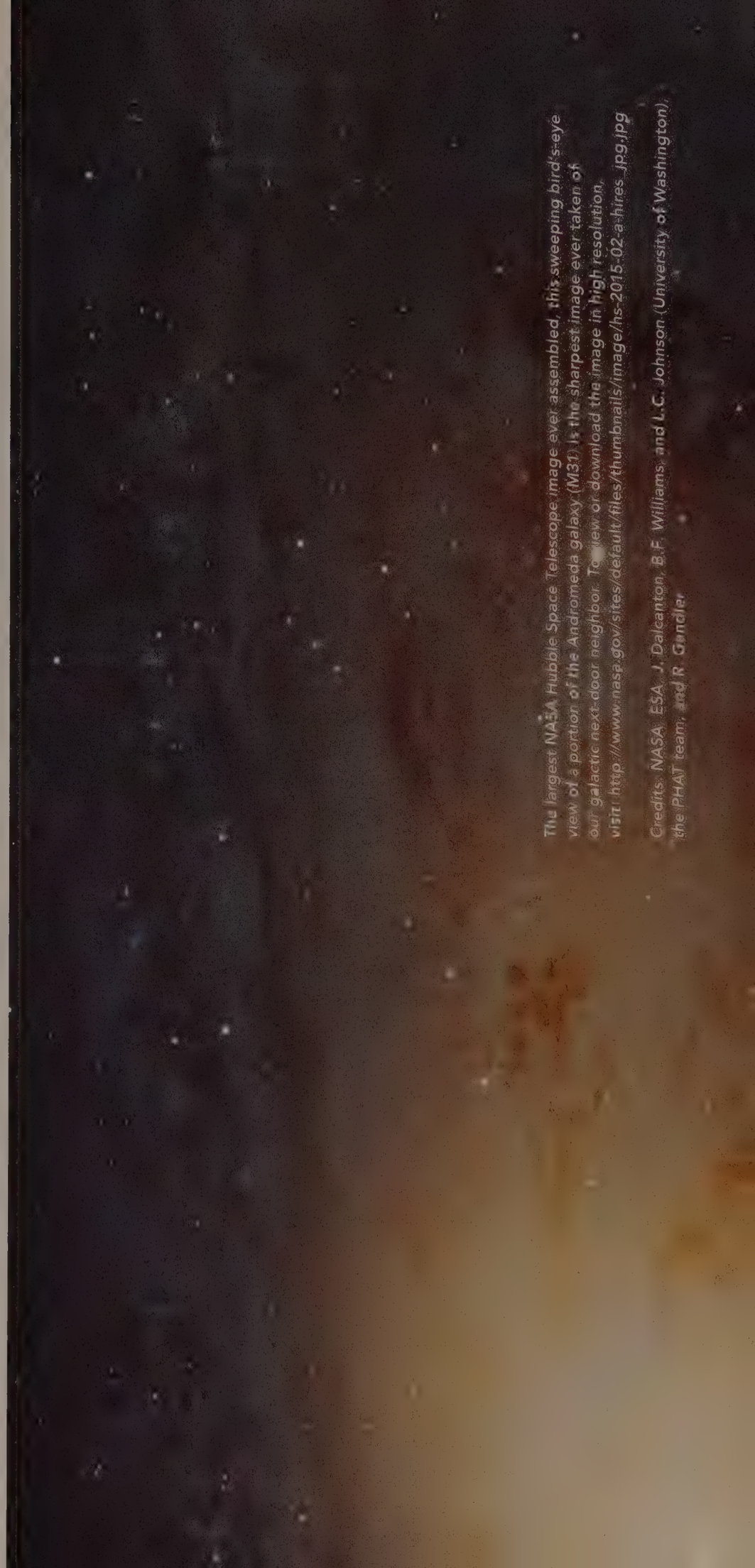
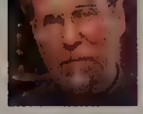


The largest NASA Hubble Space Telescope image ever assembled, this sweeping bird's-eye view of a portion of the Andromeda galaxy (M31) is the sharpest image ever taken of our galactic next-door neighbor. To view or download the image in high resolution, visit: http://www.nasa.gov/sites/default/files/thumbnails/image/hs-2015-02-a-hires_jpg.jpg

Credits: NASA, ESA, J. Dalcanton, B.F. Williams, and L.C. Johnson (University of Washington), the PHAT team, and R. Gendler



Cuckoo: *Cheating by Nature*

by Nick Davies
Bloomsbury, 2015; 288 pages, $27.00

Nick Davies is crazy about cuckoos. For the past thirty years he has spent every spring and summer hunkered down in the reedy tangle of Wicken Fen, a marshland reserve just north of Cambridge, England, where he is a professor of behavioral ecology. Readers of this elegant and lyrical report on what he has learned over the decades will easily come to share Davies' appreciation for, if not his obsession with, one of the world's more remarkable avian species.

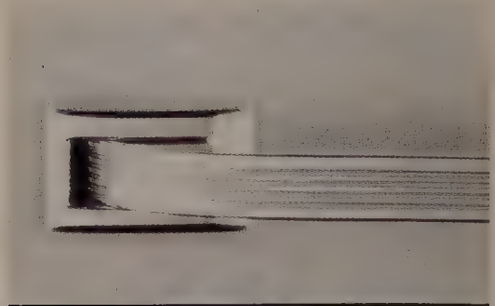
The cuckoo, common to Europe and Asia, is actually an African native that migrates north for a few months every year to breed. While its strenuous annual journey back and forth is notable, what fascinates Davies about cuckoos is their conspicuous lack of interest in good avian parenting: they build no nests, incubate no eggs, and feed no young. Instead, they lay their eggs in the nests of other species, often eject the hosts' eggs, and rely on unsuspecting victims to feed and raise their hatchlings. Adult cuckoos not only abandon their young immediately after laying, they head back to African wintering grounds even before the offspring have left the nest to join them.

As an evolutionary biologist, Davies wants to know how such odd behavior arose. How do female cuckoos get those eggs into the nest without being detected? Why don't the reed warblers, magpies, and other hosts whose nests have been invaded toss out the cuckoo eggs? How do cuckoo chicks, which are larger than the chicks of their hosts, manage to command that extra share of food they need to make it to maturity?

To answer such questions, Davies and his collaborators turn Wicken Fen into an ecological testing ground, devising numerous experiments to highlight the Darwinian processes that give cuckoos an advantage. For instance, by inserting fake eggs of various sizes and markings into reed warbler nests, they've gauged the ability of these birds to discriminate between their own and alien eggs. Though the reed warblers are good at spotting ringers, cuckoos have evolved such effective egg mimicry that they can usually fool their targets. Indeed, some bloodlines of cuckoos, which lay reed-warbler-like eggs, specialize in exploiting reed warblers, while other cuckoos, which lay pied wagtail-like eggs, specialize only in pied wagtails.

Other experiments, using loudspeakers and microphones to explore the aural landscape, have revealed how cuckoo chicks, once hatched, manage to carry on the deception. A young cuckoo, for instance, manages to get more food from its reed warbler stepparent by imitating the call of a reed warbler chick—only faster. "To our ears," Davies notes, "the cuckoo didn't sound like a single chick; it sounded more like a whole brood of hungry chicks." Those urgent calls must pull at the heartstrings of a conscientious reed warbler, which redoubles its efforts to bring insects to what it thinks is a ravenous nestful of its own young.

For Davies, studying the small deceptions of a tiny bird is a way of illuminating the bigger issues of biology, especially the role of evolutionary processes in shaping animal behavior and environmental balance. The cuckoo's tale, which appears at first glance to be an object lesson in how not to raise one's children, is, on closer inspection, an illustration of the complex web of interactions that make the natural world an abiding source of wonder and fascination.



Chilled: *How Refrigeration Changed the World and Might Do Só Again*

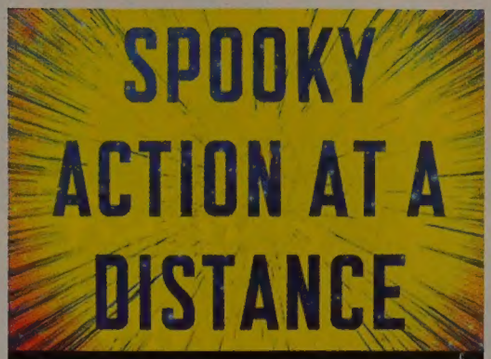
by Tom Jackson
Bloomsbury Sigma, 2015; 272 pages, $27.00

Prior to the nineteenth century, refrigeration was a luxury, reserved only for those rich and powerful enough to import ice from the mountains and store it in fortress-like ice-houses. Tom Jackson, a gifted science writer from the United Kingdom, describes the invention of modern refrigeration as a long struggle to understand the theory and practice of thermodynamics. So the story begins, aptly, with an oft-told historical narrative, a highly readable account of the progress of physics and chemistry from the seventeenth to the nineteenth centuries.

Thermodynamic history reaches a climax in 1852, with an experiment by William Thompson and James Prescott Joule that formed the basis of practical refrigeration. They put compressed gas into a container and connected it to another container holding a vacuum. The compressed gas was released into the vacuum through a thin nozzle—just like the conical nozzle on a fire extinguisher—and Presto! The temperature of the expanding gas took a nosedive. It was a short step from Joule-Thompson expansion to a practical refrigerator, in which an expanded gas is recompressed and then re-expanded in a closed loop. The cycle effectively pumps heat out of a confined space (your refrigerator-freezer compartment) and discards it to the room (the back of your refrigerator, you might have noted, gets warm as it operates).

Jackson's later chapters detail the rise of refrigeration as a global industry, beginning with nineteenth century entrepreneurs who harvested winter ice in New England and shipped it to households as far away as Calcutta. These ice barons were the first to adopt refrigeration machines, based on the Joule-Thompson effect, when they became available in the mid-1800s. The earliest refrigerators were behemoths, only usable by existing ice companies as an alternative to naturally harvested ice. The compact domestic refrigerator, which effectively ended the need for ice deliveries, did not become available until the early 1900s. A 1911 model offered by General Electric bore a luxury price of $1,000, twice the cost of an automobile. But improved models soon turned refrigeration into a necessity—by 1955 there were forty million refrigerators in the United States alone.

The modern world would not exist without refrigeration. Jackson describes the "cold chain" of chilled transport and storage which is essential to feeding the world and supporting urban society. He details the uses of refrigeration in air-conditioning, and in high-tech applications such as medical imaging and cloud computing. By the final chapter, readers will appreciate Jackson's witty opening line: "... it is perhaps becoming clearer why Paleolithic man had little trouble torching a wooden stick, but had to wait several dozen millennia before he could put an ice-lolly on it."



Spooky Action at a Distance: *The Phenomenon that Reimagines Space and Time—and What it Means for Black Holes, the Big Bang, and Theories of Everything*
by George Musser
Scientific American/Farrar, Straus, and Giroux, 2015; 304 pages, $26.00

A specter is haunting physics: the ghostly notion of "nonlocality." It's an idea so alien to our sense of how the world works that even trained physicists, who are used to the bizarre insights of relativity and quantum mechanics, find it difficult to understand, much less accept. Briefly put, it's the fact that two particles, separated by whatever distance you choose, can—under the proper conditions—act as if they were in intimate contact.

Two photons, for instance, generated in quantum processes so that they are "entangled," are sent off in opposite directions. Though the polarization (the plane of vibration) of each photon is random and undetermined until actually measured, physicists have found that measurements of the polarization of one photon are immediately correlated with the polarization of its entangled twin, even if the measurements are made when the two particles are separated by kilometers. This experiment has been performed over and over in recent years.

Einstein, who proposed a similar experiment with colleagues Boris Podolsky and Nathan Rosen in a 1935 paper, called such a phenomenon "spooky action at a distance," and worried that if it were true, the very notion of space might fall apart, and with it "nothing will remain...of the rest of contemporary physics." While he granted that quantum mechanics appeared to require nonlocality, Einstein felt that something was missing, and that a more satisfying theory, which preserved a sensible notion of discrete points in space, would eventually be found.

George Musser, a veteran science writer, has described such quantum weirdness in numerous articles in *Scientific American* over the years. In this ambitious book, he surveys the progress that has been made in addressing nonlocality since Einstein's seminal paper. If anything, the mystery has deepened. Not only have laboratory experiments confirmed that entangled particles act as if they are in two places at the same time, but discoveries on a cosmic scale suggest similar influences that travel impossibly fast. The background microwave radiation from the big bang, which comes to us over distances of almost fourteen billion light years, is remarkably uniform over the entire sky. How can that be? Two spots in the sky 180 degrees apart are separated by twenty-eight billion light years, far too long for any signal to have traveled that far at the speed of light.

"Space and time," Musser cautions, may be "the products of some deeper level of reality." He has interviewed a host of theoretical physicists and philosophers of science, who weigh in with creative ideas about what that reality might be, ranging from strange underlying fields to the mind-boggling particles traveling backwards in time. While the author has done a monumental job of translating recondite theory into laymen's terms, through example and analogy, the going may be rough, and there will be patches of prose—e.g. "some of the D0-branes became entangled and started to behave as a single unit..."—that may make you take a timeout to clear your head before proceeding. Don't feel inadequate—quantum physicists, even if they are better at the math, are puzzled, too.

Laurence A. Marschall is a professor of physics at Gettysburg College in Pennsylvania. His most recent books, coauthored with Stephen P. Maran, are Pluto Confidential: An Insider Account of the Ongoing Battles over the Status of Pluto *and* Galileo's New Universe: The Revolution in Our Understanding of the Cosmos *(both BenBella Books, 2009).*

Mixed Feelings

BY JASON MARK

The coyotes woke me up, a whole pack, howling in the moonless night—a chorus of coyotes on the edge of the wilderness. There came another howl—this one from the other side of our camp. It was much different from the others, a deeper voice, almost baritone: *Aaarrrr-oooooo.* A storybook sound that went beyond memory and into imagination.

GARY KRAMER/USFW

Mexican gray wolf, "Lobo," Canis lupus baileyi

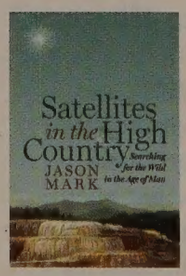
In the weeks leading up to this expedition to New Mexico's Gila Wilderness, I had told myself again and again not to expect any wolf encounters. These were not the famous wolves of Yellowstone I was tracking. Instead, I was after the Mexican gray wolf, the Rocky Mountain wolf's smaller cousin. Less famous, perhaps, but just as polarizing: hated, celebrated, beloved, protected, and managed at huge cost and effort. At the time, there were just eighty-three known wolves in thirteen packs roaming the wooded mountains of Arizona and New Mexico, yet they had caused much conflict among their human neighbors.

Animals are a portal into wildness. With their autonomy and their native indifference to us, wild animals force us to consider that other beings have a will of their own, a set of interests distinct from ours. No other animal provokes such intense feelings of both attraction and repulsion as do wolves. Adolph Murie (1899-1974), a longtime ranger in Alaska's Denali National Park and a pioneer of carnivore biology, once said, "Wolves are the voice of wilderness." Theodore Roosevelt, in his 1908 book *Hunting the Grisly and Other Sketches,* scorned the wolf as "the beast of waste and desolation." Centuries earlier, European Christians feared the wolf as the devil in disguise. The Cheyenne and the Arapaho viewed the wolf as the spirit-animal of power and courage, but the Navajo believed it was a witch.

Our conflicting emotions about wolves—with their big appetites and their guile—may have more to do with our species' similarities than with any differences. Read a bit of *Canis lupus* biology, and after a while the wolf tales begin to sound Shakespearean—a tumult of rapaciousness, generosity, fratricide, outcasts and loners, loyalty and affection.

I feel sorry for how the wolf has been freighted with our parables, at this point a weight heavier than any radio collar. The wolf, I make myself remember, is just an animal, not any more "solvable" than human nature. Toward the end of his 1978 book, *Of Wolves and Men,* Barry Lopez, after having spent hundreds of pages plumbing the depths of our mixed-up wolf myths, delivers a stern warning against overthinking: "We assume that the animal is entirely comprehensible. It seems to me that this is a sure way to miss the animal and to see, instead, only another reflection of our own ideas."

Once we strip away all of the legends, what do we have left? While some hunter-gatherers esteemed the wolf, agriculturalists have always despised it—and for some good reasons. Our relationship with the wolf is so vexed because, perhaps more than any other animal, the wolf is our direct competitor. For millennia, a wolf pack at the edge of the pasture meant the difference between a season of bounty and one of famine. This ancient rivalry forces hard choices: Can we find a way to live with the wolf's wildness and share space together? Can we coexist, and come to see another carnivore as something of an equal, and not just an enemy? Or do we have to control it, and in that control limit its wildness, the very thing that draws us to it?



Excerpted from *Satellites in the High Country: Searching for the Wild in the Age of Man* by Jason Mark. Published October 2015 by Island Press. Copyright © Island Press. All rights reserved.

JASON MARK is the longtime editor of Earth Island Journal, *a quarterly magazine. He is a co-founder of San Francisco's largest urban farm. His writings on the environment have appeared in* The New York Times, theatlantic.com, The Nation, *and* salon.com, *among many other publications. For more, visit* jasondovemark.com.

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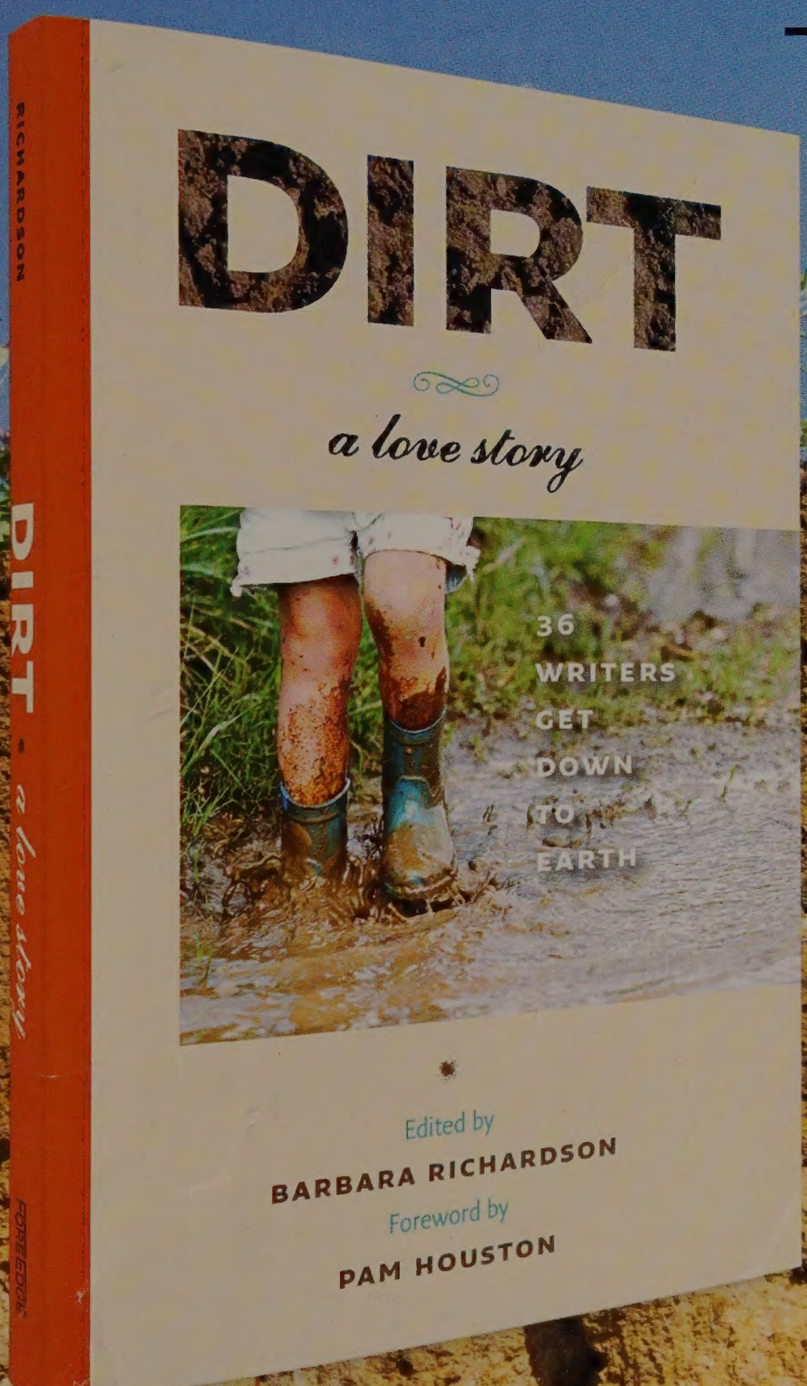

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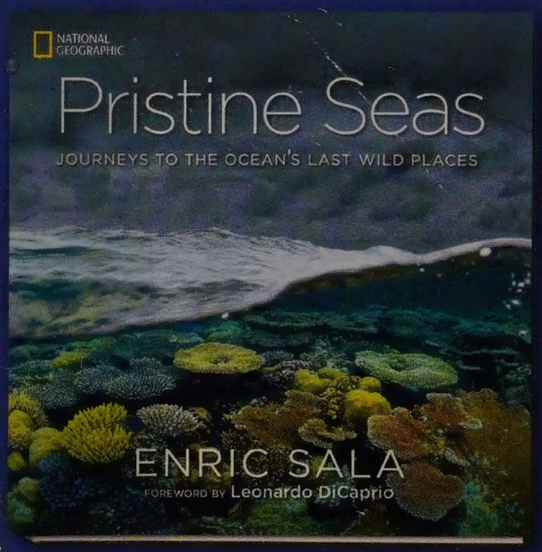

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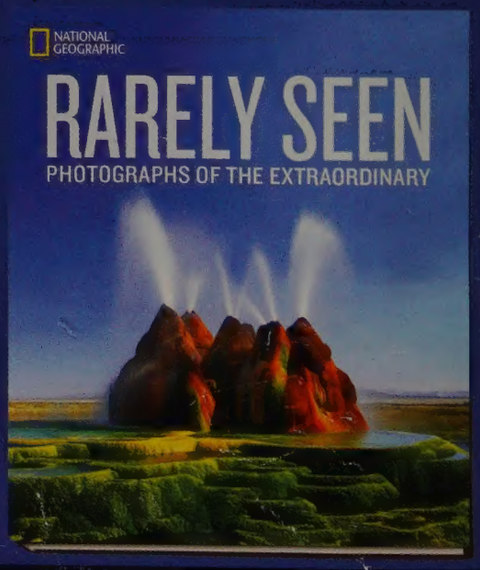

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